AD-A008 207

COMBAT TRACTION II, PHASE II. VOLUME II, DETAILED RESULTS OF SENSITIVITY STUDY AND PREDICTION MODEL CALCULATIONS

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Boeing Commercial Airplane Company

Prepared for:

Federal Aviation Administration
Aeronautical Systems Division
National Aeronautical and Space Administration

October 1974

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ASD-TR-74-41 FAA-RD-74-211 Volume II	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER AD-A008 207
4. TITLE (and Subtitle) Combat Traction II, Phase II Volume II, Detailed Results of Sensitivity Study and Prediction Model Calculations		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M.K. Wahi, S.M. Warren, R.L. Amberg, H.H. Straub, and N.S. Attri		8. CONTRACT OR GRANT NUMBER(s) F33657-74-C-0129
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Boeing Commercial Airplane Company Renton, Washington		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 021A9363
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Systems Command Andrews AFB, Maryland		12. REPORT DATE October 1974
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Deputy for Subsystems Aeronautical Systems Division Wright-Patterson AFB, Ohio		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release, Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Combat Traction
DBV
Mu-Meter
Anti-Skid
Simulator

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report details the results from the Sensitivity Study portion of the Com : Traction II, Phase II Program and also contains the calculations resulting from prediction equat n formulation. The objectives, results, and recommendations of this effort are contained in ASD Technical Report ASD-TR-74-41, Volume I.

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SECTION I

INTRODUCTION

This volume describes the hardware and antiskid systems used on the brake control simulator plus the test conditions and parameters used in developing data for the dimensional analysis in the study. Details of the specific pi-term calculations and of the development of component and dimensional prediction equations are presented as backup information for ASD-TR-74-41, Volume I.

SECTION II

BASIC BRAKE CONTROL HYDRAULIC SYSTEM

The hydraulic portion of the brake control simulator employed standard aircraft hydraulic system components. The actual hydraulic configuration of each of the five aircraft was mocked up. The major components common to most of the aircraft braking systems are:

- Antiskid valve
- Pilot metering valve
- Brakes
- Accumulator
- Shuttle valve
- Tubing

To generate the proper hydraulic system response, line lengths and diameters, valve locations, and restrictions were implemented as specified by the technical documents for each airplane. The brake hydraulic system of each aircraft is activated by a pilot input to the pilot metering valve. The pilot brake pedal action was simulated by opening the metering valve and supplying the antiskid valve with a dump signal removing all brake pressure until braking was initiated. At the time of brake application, the dump signal was ramped off in 0.4 sec. This method successfully modeled a typical pilot response in initiating braking, judging from Boeing flight test results of performance landings.

The main function of the antiskid valve is to modulate the brake pressure based on an electrical signal from a control box. To maintain the proper pressure and flow characteristics through the antiskid valve and pilot metering valve, actual aircraft brakes were used. This ensured that the correct pressure-volume relationship existed during system operation. Because the system pressure is modulated by the antiskid valve, large demands can be placed on the hydraulic supply. To partially eliminate the resulting supply pressure fluctuations, an accumulator is placed in the system supply line.

The remaining component, the shuttle valve, is used in conjunction with the emergency braking system. Although the emergency system was not simulated, the shuttle valve was employed to obtain the proper flow restriction.

SECTION III
BOEING 727 BRAKE CONTROL SYSTEM DESCRIPTION AND SYSTEM CHARACTERISTICS

The Boeing 727 braking system contains four basic elements: wheel speed transducers, antiskid control system, hydraulic system, and brakes. The hydraulic system includes antiskid valves, pilot metering valves, deboost valves, and the associated tubing. An overview of the braking system mockup is shown in Figure 1. The detailed hydraulic schematic presented in Figure 2 identifies individual components shown in Figure 1. Table 1 lists line dimensions and materials used in the mockup.

1. SYSTEM DESCRIPTION

a. WHEEL SPEED TRANSDUCER

The Boeing 727 wheel speed transducer provides instantaneous wheel speed information to the control unit. The transducer, as pictured in Figure 3, is a variable-reluctance device producing an alternating current proportional to wheel speed. The device is self-contained and is mounted in the axle. It contains a rotor and stator, each having 50 teeth. A magnetic field is established by a supply current to the stator coil. As the rotor turns, the variation in the air gap between the teeth of the rotor and stator induces an alternation in the supply current. The AC frequency is proportional to wheel speed and is used as the input to the antiskid control box. The transducer produces a sinusoidal signal at 50 cycles per wheel revolution.

b. ANTISKID CONTROL SYSTEM

The antiskid control system used during the sensitivity analysis of the Boeing 727 was the Hytrol Mark II skid control system manufactured by Hydro-Aire. A simplified block diagram of the Mark II System is presented in Figure 4.

The Mark II antiskid system requires active wheel speed inputs. This information is provided by the wheel speed transducers. The AC signal produced by the transducer is converted to a DC voltage in the control box by the squaring circuit and velocity amplifier.

The squaring circuit converts the sinusoidal wheel speed signal to a square wave with frequency proportional to the wheel speed. The velocity amplifier then reduces the square wave to a DC voltage. The level of the DC voltage is a measure of the true wheel speed.

The DC wheel speed is differentiated in the rate amplifier to produce instantaneous wheel deceleration. This deceleration is compared to a fixed threshold value; when the actual wheel deceleration exceeds the threshold, a brake release signal is initiated. The duration and magnitude of the brake release is based on the absolute wheel speed departure. In addition to this proportional control, the pressure bias modulation (PBM) circuit provides an extension of the original control signal after the wheel has recovered from a skid. During a skid, the PBM is charged to a level proportional to the duration and magnitude of the skid. After the wheel has recovered from a skid, the PBM discharges ramping pressure on. To

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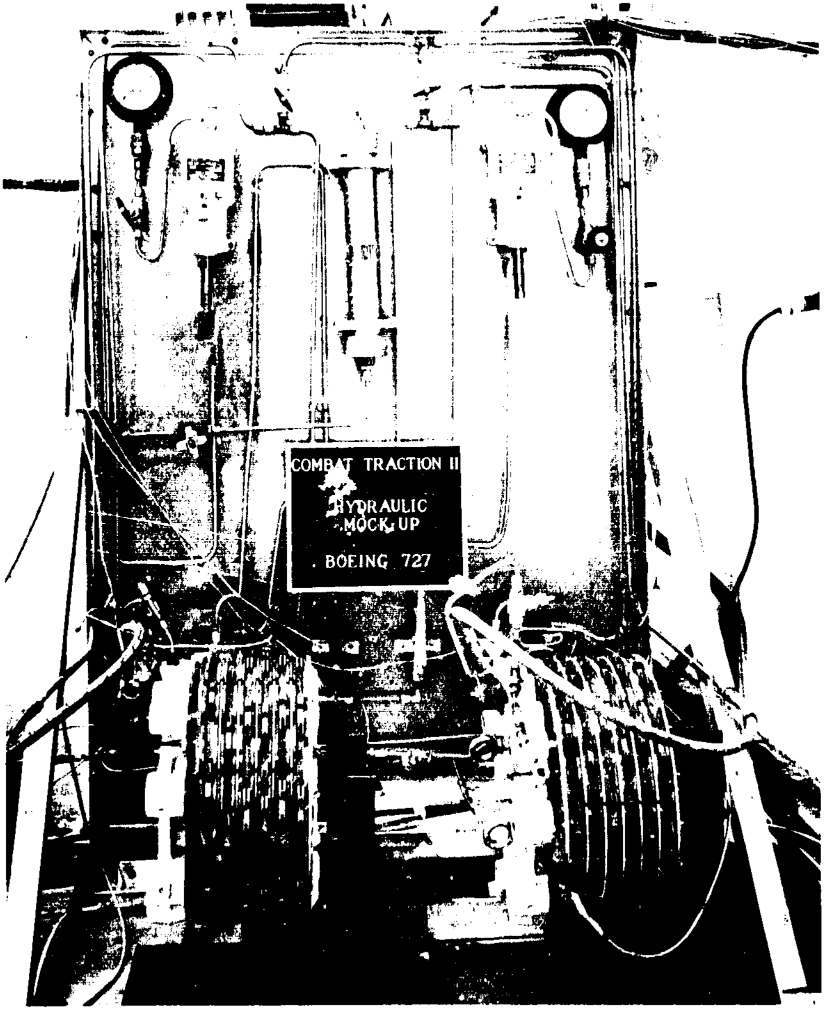

Figure 1. 727 Brake Hydraulic System Mockup

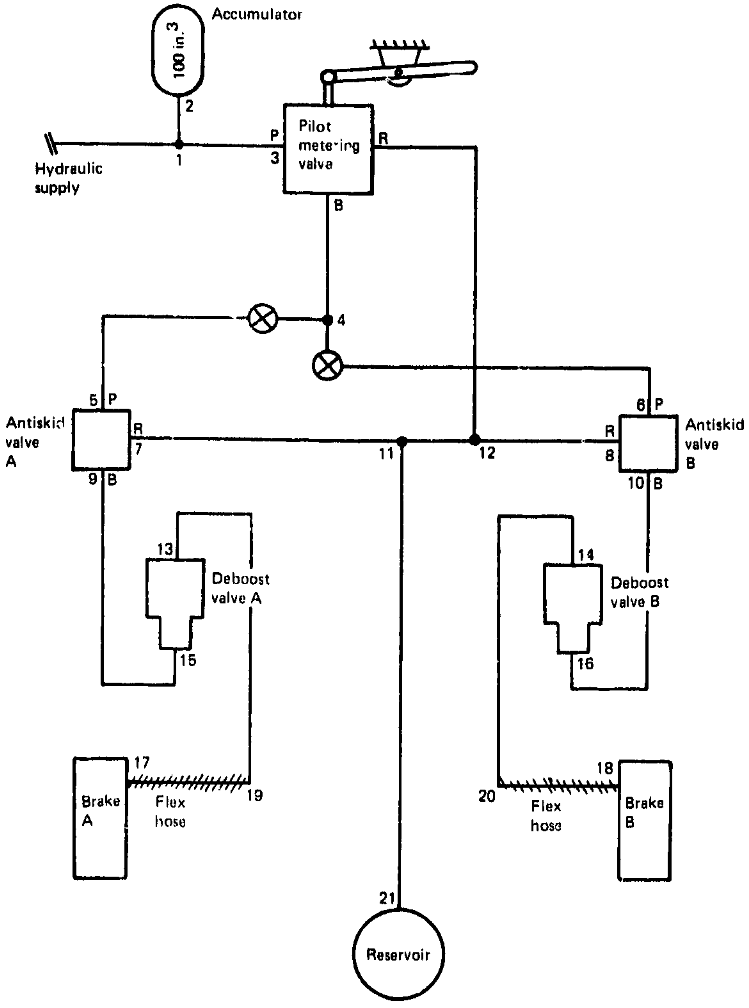

Figure 2.—727 Brake Hydraulic System Schematic

Table 1.—727 Brake Hydraulic System Mockup

Description	Index point (from-to)	Line size	Line length (in.)
Common supply line	1-2 1-3		32 65
A-system metered pressure line	4-5	6S	160
A-system brake line	9-15 13-19 17-19	6S 8S Hose	156 87 36
B-system metered pressure line	4-6	6S	162
B-system brake line	10-16 14-20 18-20	6S 8S Hose	165 88 36
Return line	8-12 7-11 11-21	 12S	15 30 428

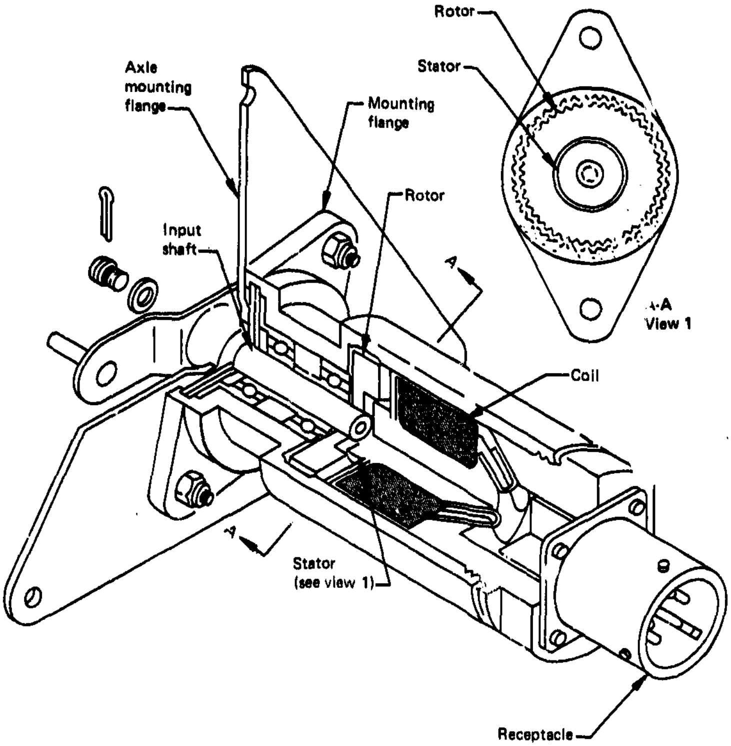

Figure 3.—727 Wheel Speed Transducer

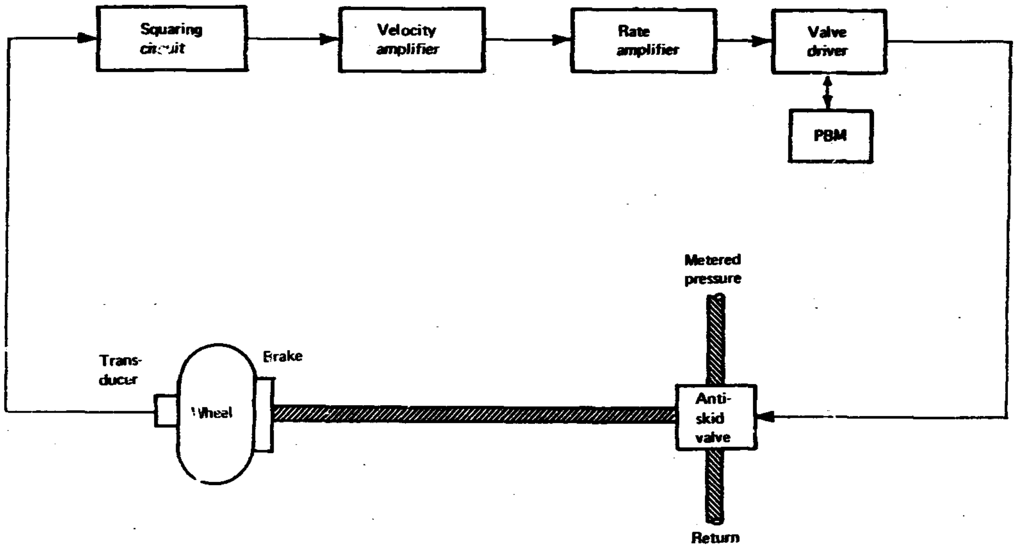

Figure 4.—727 Mark II Antiskid System Block Diagram

ensure that the same brake pressure is not reapplied after a skid, the PBM is charged to a higher value than it had prior to the skid.

The remaining component of the system is the valve driver, which provides current to the antiskid servo valve for a given voltage input from the rate amplifier.

c. TOUCHDOWN AND LOCKED-WHEEL PROTECTION

Locked-wheel protection consists of an arming circuit and a locked-wheel detection circuit The system is armed when either of two paired wheels are rotating faster than 20 knots. The wheel pairs are the right and left inboard wheels and the right and left outboard wheels. If the system is armed and the wheel speed decreases to a speed below 20 knots, a signal is produced to completely release brake pressure. The system tested incorporated a modification that delays system disarming for a period of time after both wheels decrease to a speed below the arming speed. This modification permits retention of locked-wheel protection if both wheels lock simultaneously.

Squat switch logic arms the system in the air to provide touchdown protection.

d. BRAKE HYDRAULIC SYSTEM

The hydraulic system is composed of antiskid valves, pilot metering valves, deboost valves, and the associated tubing.

The 727 brake hydraulic system requires a 3000-psi supply pressure. The 3000-psi supply enters the actual brake hydraulic system at the pilot metering valve. This valve is a pressure control valve that supplies pressure to the antiskid valve based on pilot input. The pilot can meter from zero to 3000-psi pressure depending on his input. The metered pressure is the maximum attainable output pressure of the antiskid valve. The actual output of the antiskid valve is, however, controlled by the electrical signal from the skid control box.

The antiskid valve, produced by Hydro-Aire, is pictured in Figure 5. It is a two-stage pressure control valve with a flapper and nozzle first stage and sleeve and spool second stage. The flapper is operated by a permanent magnet torque motor. The application of an electrical signal from the antiskid control box to the torque motor causes the flapper to move from the neutral position (maximum pressure). Movement unbalances the hydraulic bridge formed by the first stage nozzles. The resulting differential pressure is applied to the second stage spool. Movement of the spool allows the output of the antiskid valve to change. The hydraulic forces on the spool work to position the spool and reach an equilibrium position and pressure.

The modulated pressure from the antiskid valve is reduced at the deboost valve before entering the brake. The deboost valve reduces the pressure by the ratio of 0.57 to 1.0. The pressure output of the deboost valve is transmitted through a shuttle valve to the brakes.

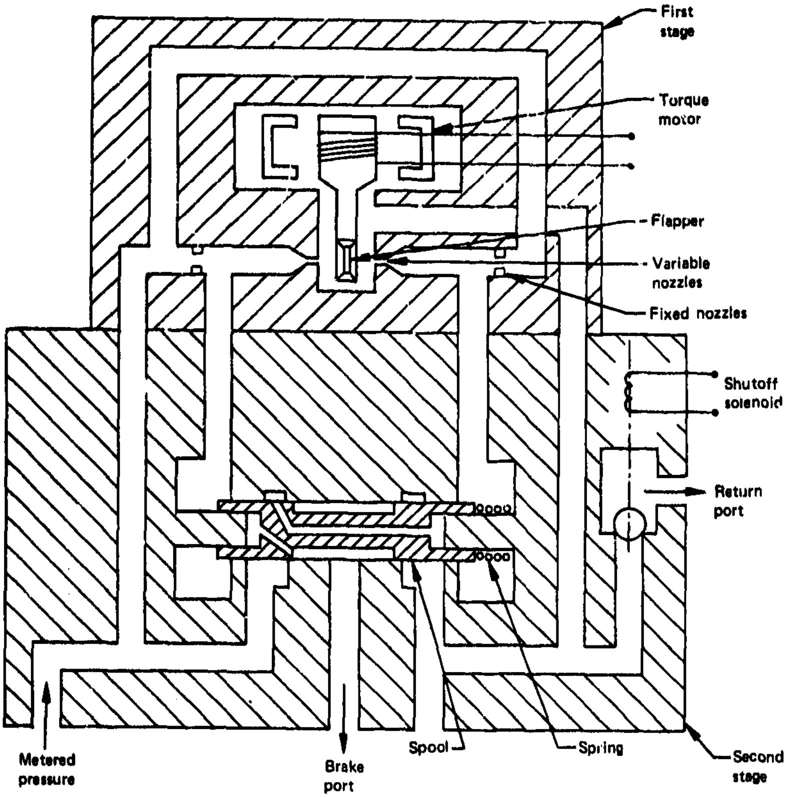

Figure 5.—727 Antiskid Valve Schematic (Shown Deenergized)

e. BRAKES

The 727 brakes used in the mockup were a Bendix product (both Bendix and B. F. Goodrich brakes are available). They are six-rotor steel brakes. The modulation of pressure at the brake causes compression or release of the disc stack, which results in a controlled braking action.

2. BRAKING SYSTEM CHARACTERISTICS

During the senstitivity study, various system and component characteristics were measured. The dynamic response of the standard 727 hydraulic system is shown in Figures 6 and 7. Figure 6 plots the system frequency response, while Figure 7 represents step response. Tables 2 and 3 compile the dynamic response data resulting from hydraulic system changes.

Figure 8 plots the antiskid valve pressure-current characteristics. The effect of varying the pilot's metered pressure is depicted by the three different curves.

The pressure-volume characteristics of the standard 727 brake are shown in Figure 9. Also included are the p-v relationships for the increased brake volume and increased brake gain test conditions.

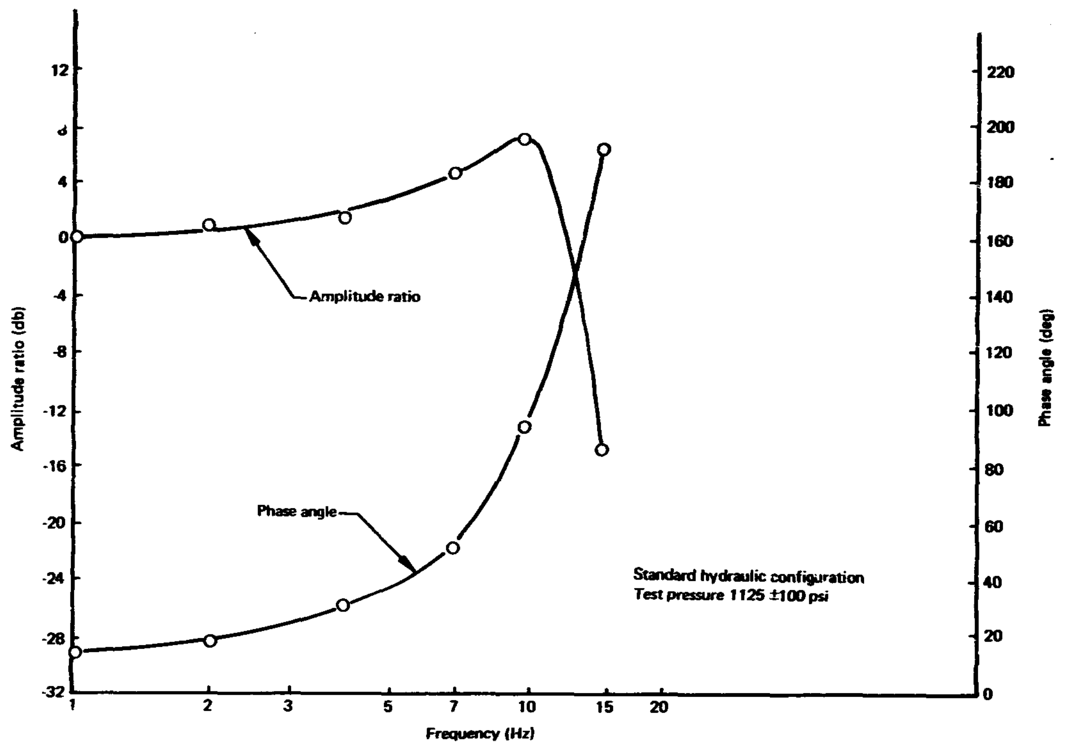

Figure 6.—727 Brake Hydraulic System Frequency Response

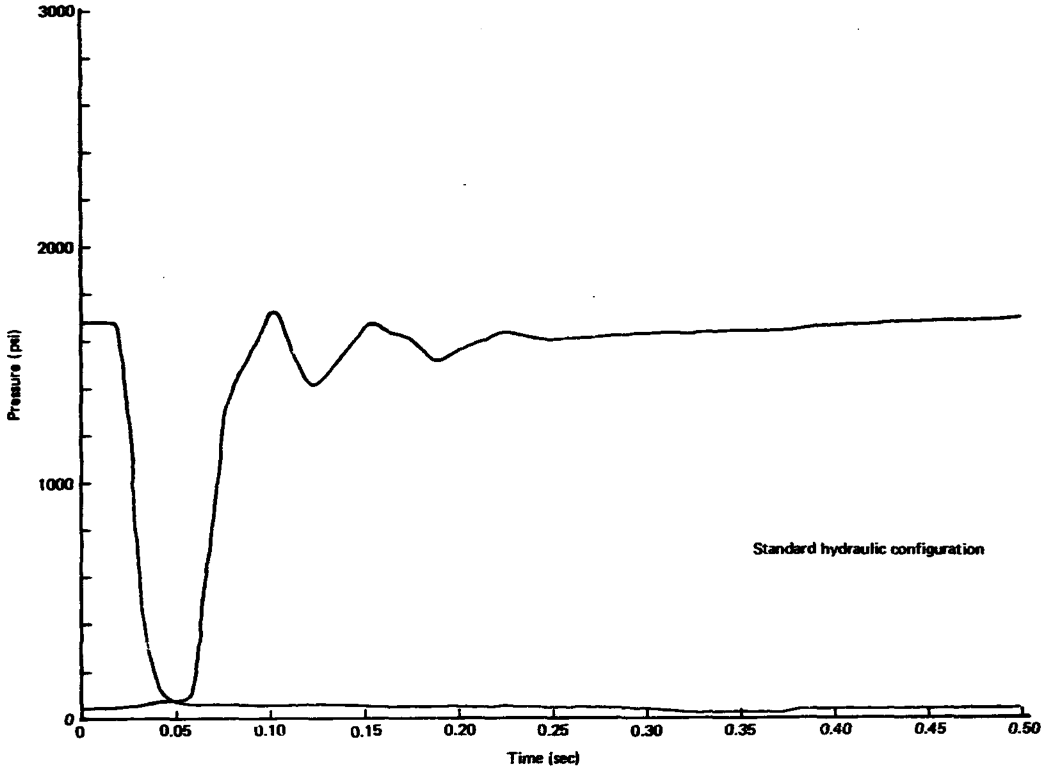

Figure 7.—727 Brake Hydraulic System Step Response

Table 2.—727 Frequency Response Data

Test condition	Test pressure (psi)(±psi)		Resonance point frequency or -3 db frequency (Hz)	Gain at resonance or -3 db (db)	Phase angle at resonance or -3 db (deg)	Frequency at 90° phase angle (Hz)
Standard	1125	100	10	7	94	9.8
		200	10	6	81	10.4
	563	100	9.5	6	102	8.9
		200	9	4.9	92	8.9
a. Decrease line diameter	1125	100	6	4.1	79	6.4
		200	7	2.3	91	7.0
	563	100	5	3.6	67	6.0
		200	6	2.2	78	6.1
b. Increase line	1125	100	7	4.1	86	7.2
		200	8	2.6	86	8.3
	563	100	5.5	2.0	75	6.3
		200	7.6	-3.0	124	6.2
c. Move dynamic breakpoint out 150% of nominal	1125	100	10	4.5	76	11.0
		200	12	4.5	78	12.9
	563	100	9	4.6	69	10.3
		200	10	4.8	69	11.3
d. Move dynamic breakpoint in 50% of nominal	1125	100	7	5.8	88	7.1
		200	8	6.3	94	7.8
	563	100	8	10.6	126	6.9
		200	7	6.2	90	7.0
e. Restriction	1125	100	9	5.1	84	9.3
		200	10	6.2	82	10.5
	563	100	9	5.4	86	9.2
		200	9	6.2	82	9.4

Table 3.—727 Step Response Data

Test condition	Pressure step change	Delay response time (sec)		Response time to 80% of pressure change (sec)		Percentage pressure overshoot of step change	
		Pressure increase	Pressure decrease	Pressure increase	Pressure decrease	Pressure increase	Pressure decrease
Standard configuration	0-1700	0.060	0.020	0.080	0.035	1.8	0
	0-1500	.065	.015	.085	.032	18.0	0
	0-850	.095	.015	.115	.037	10.6	0
	250-1700	.015	.012	.035	.027	13.8	11.7
	250-1500	.015	.015	.035	.025	24.0	13.6
a. Decrease line diameter	0-1700	.075	.020	133	.060	4.1	0
	0-1500	.075	.015	.135	.050	9.3	0
	0-850	.115	.015	.182	.050	5.9	0
	250-1700	.013	.020	.057	.050	11.0	10.3
	250-1500	.015	.015	.055	.043	16.0	12.0
b. Increase line diameter	0-1700	.105	.020	.257	.063	3.5	0
	0-1500	.105	.015	.260	.055	3.3	0
	0-850	.140	.015	.445	.067	9.4	0
	250-1700	.020	.020	.070	.052	0	11.7
	250-1500	.015	.012	.055	.030	0	16.8
c. Move dynamic breakpoint out 150% of nominal	0-1700	.055	.015	.077	.030	0	0
	0-1500	.057	.010	.085	.023	2.7	0
	0-850	.085	.010	.112	.025	3.5	0
	250-1700	.012	.017	.032	.028	9.7	14.5
	250-1500	.010	.010	.027	.020	20.8	16.8
d. Move dynamic breakpoint in 50% of nominal	0-1700	.065	.025	.090	.040	5.9	0
	0-1500	.070	.017	.095	.035	16.0	0
	0-850	.100	.020	.127	.037	15.3	0
	250-1700	.017	.017	.042	.032	13.8	13.2
	250-1500	.017	.017	.040	.035	25.6	16.8
e. Insert 20% return line restriction	0-1700	.065	.020	.075	.032	4.7	0
	0-1500	.057	.012	.083	.027	14.7	0
	0-850	.090	.012	.115	.030	12.9	0
	250-1700	.012	.020	.032	.033	16.6	14.5
	250-1500	.012	.010	.032	.025	24.0	16.8

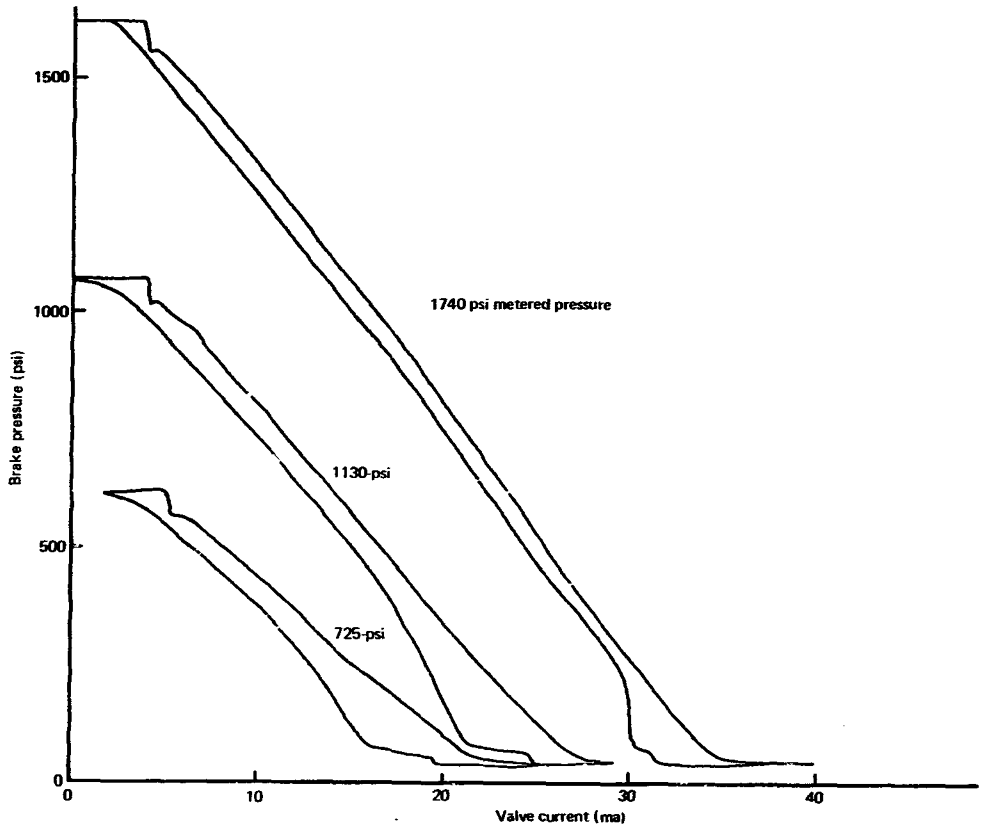

Figure 8.—727 Antiskid Valve Pressure-Current Characteristics

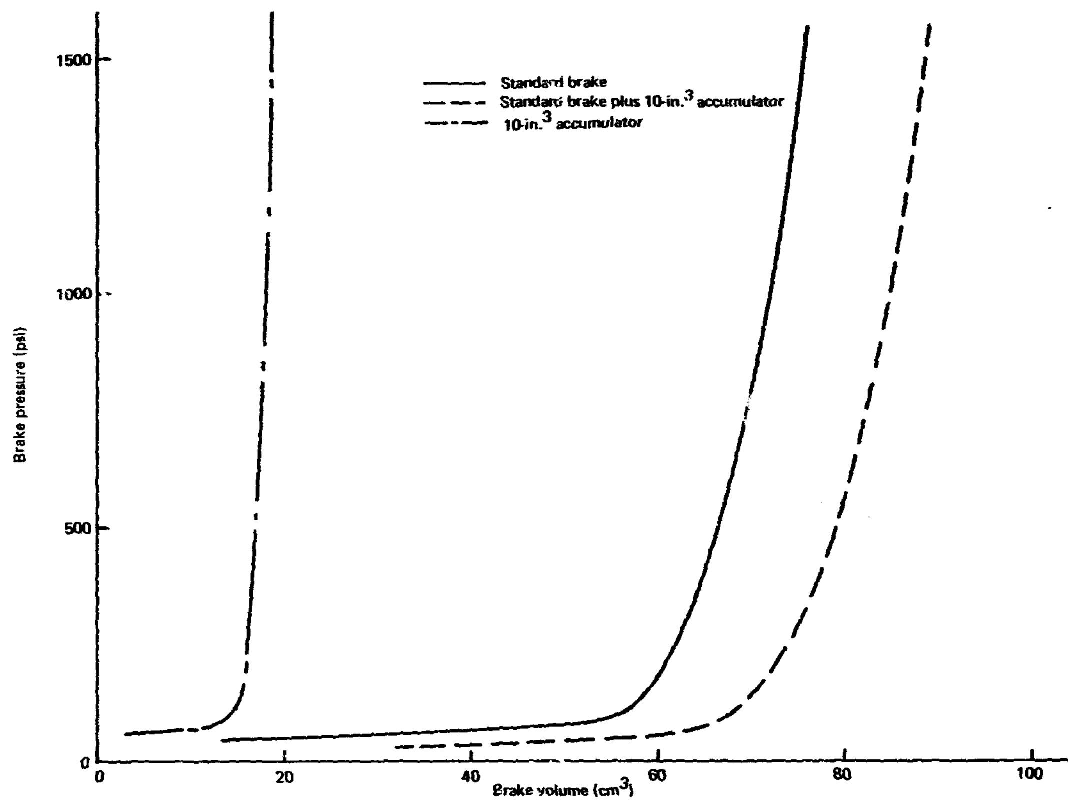

Figure 9.—727 Brake System Pressure-Volume Characteristics

SECTION IV

BOEING 737 BRAKE CONTROL SYSTEM DESCRIPTION AND SYSTEM CHARACTERISTICS

The Boeing 737 brake control system consists of four elements: wheel speed transducers, antiskid control system, hydraulic system, and brakes. The braking system mockup, exclusive of the antiskid control box, is shown in Figure 10. A schematic of the hydraulic system is given in Figure 11, and the associated line materials, lengths, and diameters are listed in Table 4.

1. SYSTEM DESCRIPTION

a. WHEEL SPEED TRANSDUCER

The 737 wheel speed transducer, pictured in Figure 12, is a self-contained device mounted in the axle. The transducer has two functional parts, a rotor and stator, each of which is made of ferrous material and has 150 teeth. A magnetic field is established by supplying current to the stator coil. As the rotor turns, the alternating alignment and misalignment of the teeth in the rotor and the stator vary the reluctance in the magnetic current. This results in an alternation in the supply current, which generates an AC frequency proportional to wheel speed.

b. ANTISKID CONTROL SYSTEM

The Boeing 737 incorporates the Mark III Skid System manufactured by Hydro-Aire for brake control. The system is represented by the functional block diagram in Figure 13. The wheel speed transducers in each braked wheel provide the instantaneous wheel speed information required by the control circuit. The transducer AC signal is converted to a DC voltage in the frequency converter block. This DC voltage is directly proportional to the actual wheel speed.

A reference aircraft velocity is provided by the reference velocity and reference deceleration functions shown in the block diagram. At touchdown, the velocity comparator develops a negative error signal, which forces the velocity reference to increase until the error signal ceases. In this manner, the reference velocity is initialized at touchdown for the braking condition to follow. During the recovery from a skid, the wheel spinup action results in a reinitialization of the reference velocity.

The reference deceleration function provides an output derived from the gradually changing component of wheel speed; thus, the output is proportional to wheel deceleration. The reference deceleration is an input to the reference velocity function; it modifies the rate of velocity decay as a function of the prevailing wheel condition.

The signals from the frequency converter and the reference velocity function are summed in the velocity comparator. The output of the comparator is a velocity error signal that drives the control circuit, resulting in pressure modulation at the brake. The control circuit, consisting of the pressure bias modulation (PBM), transient control, and lead circuits, is responsible for normal system control.

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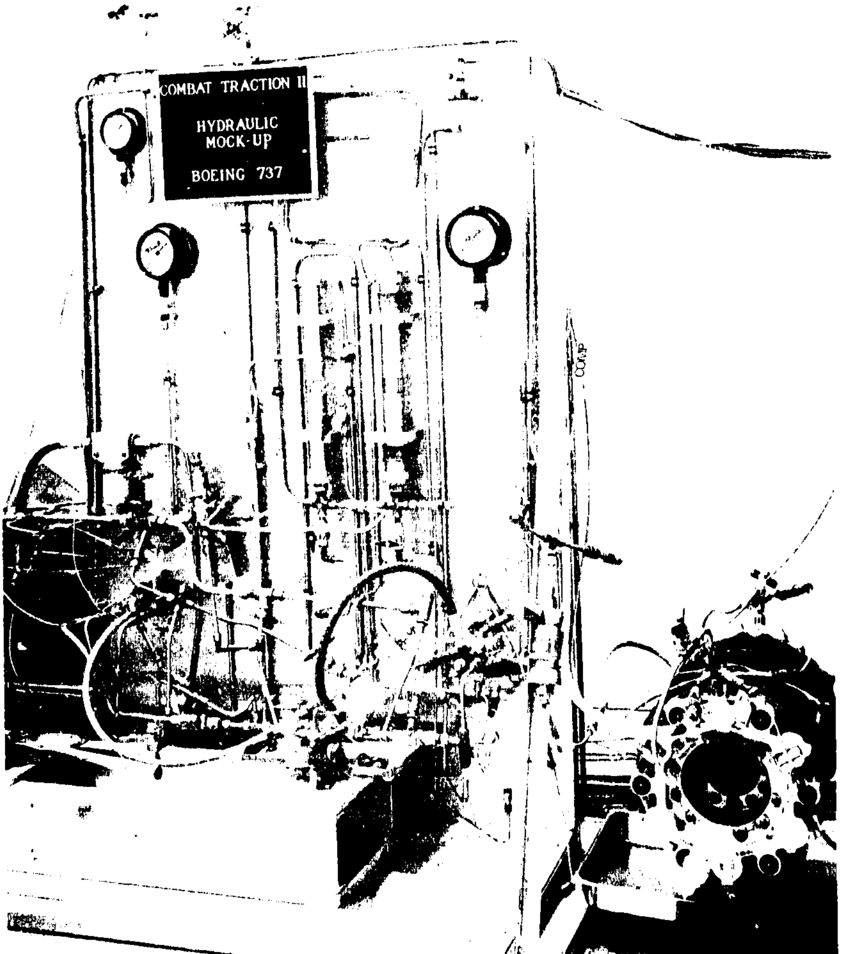

Figure 10. --737 Brake Hydraulic System Mockup

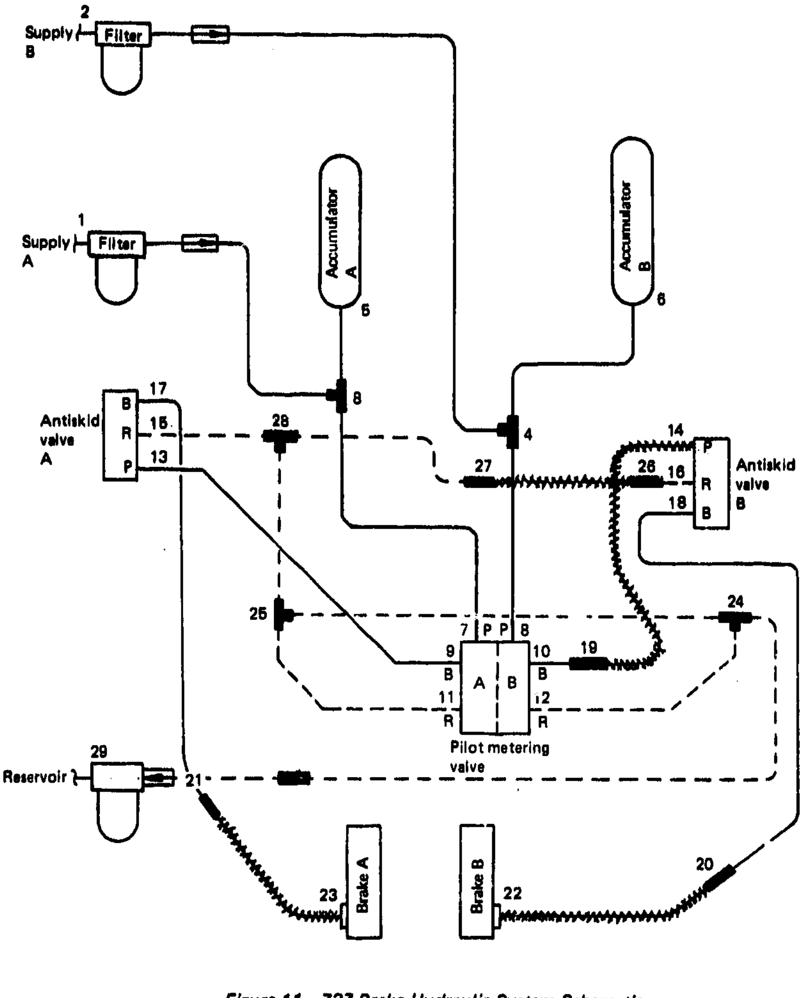

Figure 11.—737 Brake Hydraulic System Schematic

Table 4.—737 Brake Hydraulic System Mockup

Description	Index point (from-to)	Line size	Line length (in.)
A-system supply line	1-3 3-5 3-7	6S35 6S28 6S28	71 71 28
A-system metered pressure line	9-13	6S28	31
A-system brake line	17-21 21-23	6S28 3/8 hose	151 38
A-system return line	15-28 11-25	6S28 6A35	31 14
B-system supply line	2-4 4-6 4-8	6S28 6S28 6S28	13 33 118
B-system metered pressure line	10-19 19-14	6S28 3/8 hose	3 52
B-system brake line	18-20 20-22	6S28 3/8 hose	155 38
B-system return line	16-26 26-27 27-28 12-24	6S28 3/8 hose 6S28 6A35	4 27 8 14
Common return line	24-25 25-28 24-29	8S35 6A35 8A35	15 225 43

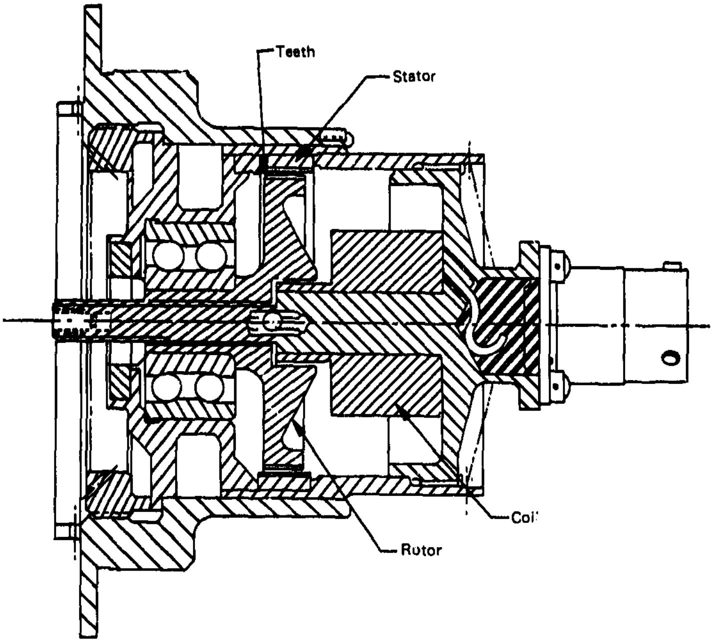

Figure 12.—737 Hydro-Aire Mark III Antiskid Wheel Speed Transducer

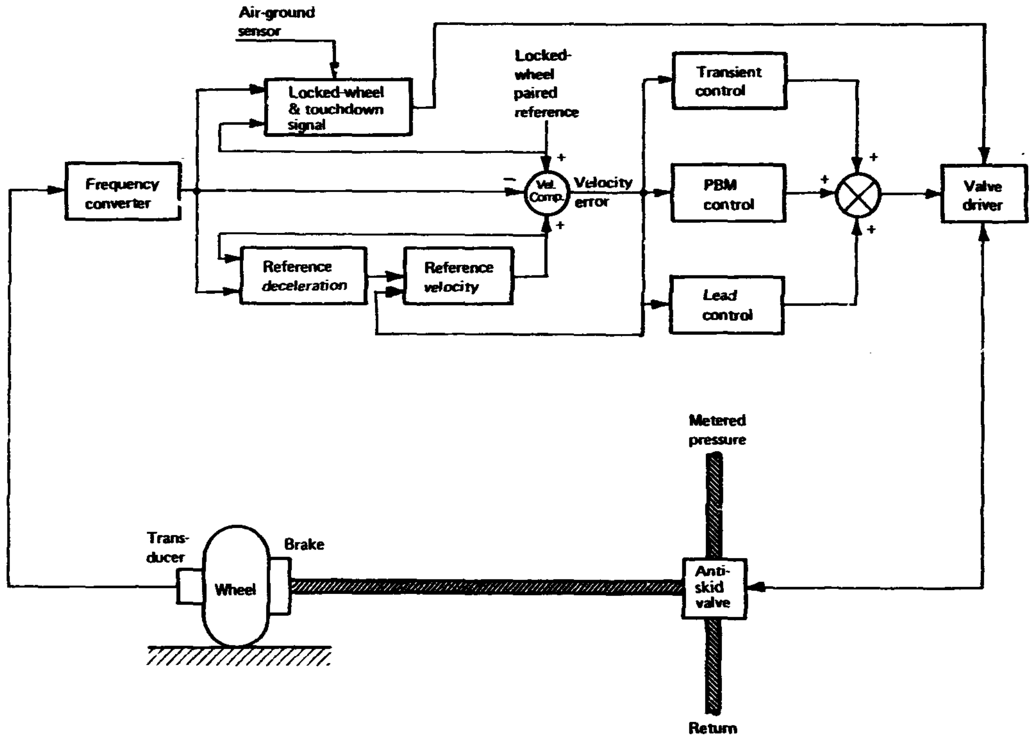

Figure 13.—737 Mark III Antiskid System Block Diagram

The PBM is the time integral of velocity error and, in comparison to the transient control, is slower to respond to error signals. The PBM determines the brake pressure when the wheel is not skidding. It reduces the pressure level during a skid and gradually increases it after the skid. In this manner, the system adapts to varying runway conditions and also seeks to keep braking at the highest possible level.

The transient control is characterized by a fixed gain and threshold. Its input is the velocity error coming from the velocity comparator and thus is a proportional control when the approporiate threshold has been exceeded. The primary purpose of the transient control is to reduce pressure quickly to provide wheel recovery from a skid.

The remaining control element, lead, is in the form of a velocity error rate, which is coupled into the summing amplifier. Since it represents the rate of velocity change, a differentiation, it provides a dynamic lead function that anticipates and initiates the brake pressure modulation to help control skids. The lead control is used to quicken the system response, thus improving efficiency. Appropriate use of lead control can also improve overall system strut damping by way of dynamic compensation.

The remaining system components include the summing amplifier and valve driver. Signals from the PBM, transient, and lead controls are summed by the summing amplifier, and this output becomes the driving function for the valve driver. The valve driver provides current to the antiskid valve proportional to the voltage from the summing amplifier.

c. TOUCHDOWN AND LOCKED-WHEEL PROTECTION

For locked-wheel protection, the inboard wheels are connected as a pair, as are the outborad wheels. The outputs of the reference velocity circuits of two paired wheels are connected to produce a signal equal to 25% of the higher of the two velocities. When the velocity of a wheel is less than this signal, a full dump signal is applied to the brake. If both wheels lock simultaneously, the normal decay time of the reference velocity will provide a continuous dump signal for a period of time. The system is armed by the squat switch logic when the airplane is in the air, thus providing touchdown protection.

d. BRAKE HYDRAULIC SYSTEM

The 737 brake hydraulic system is composed of antiskid valves, pilot metering valves, and interconnecting tubing. In addition to these components, the mockup contains the 737-200 autobrake system and its associated hardware.

The brake hydraulic system uses a 3000-psi supply; both the supply pressure and the maximum brake pressure are 3000 psi. The ships 3000-psi pressure enters the pilot metering valve. The valve is a pressure control device that regulates the pressure to the antiskid valve. The pilot supplies a manual input signal to control the output pressure of the valve. In addition to being the antiskid valve supply, the pressure from the pilot meter valve is the maximum output pressure of the antiskid valve. The actual output of the antiskid valve is controlled by the electrical signal from the skid control box.

The antiskid valve, a Hydro-Aire product, is pictured in Figure 14. The unit is a variable gain pressure control servo valve. It is a two-stage valve with a flapper and nozzle first stage and a spool and sleeve second stage. A permanent magnet torque motor in the first stage operates the flapper. In the neutral (unenergized state) the flapper is hard over against the return nozzle, permitting full control pressure to the brake. The application signal from the control box to the torque motor causes the flapper to move. The movement opens the return nozzle, allowing some flow to return and resulting in a pressure change. The pressure is applied to the second stage spool. Movement of the spool allows the output of the antiskid valve to change. The hydraulic forces on the spool work to position the spool until an equilibrium position is reached.

The pressure from the antiskid valve passes through the autobrake shuttle valve before entering the brakes.

e. BRAKES

The 737 brakes used during these tests were manufactured by Bendix. The modulation of pressure at the brake stack causes compression or relaxation of the disc stack, which results in a controlled brake action.

2. BRAKING SYSTEM CHARACTERISTICS

Various system and component characteristics were measured as part of the sensitivity study. Figures 15 and 16 depict typical dynamic response results of the standard 737 brake hydraulic system. Figure 15 plots frequency response; Figure 16 represents step response. Tables 5 and 6 are compilations of the dynamic response data obtained during testing.

Figure 17 plots the antiskid valve pressure-current characteristics. The effect of varying the pilot's metered pressure is also shown.

The pressure-volume characteristics of the standard 737 brake are shown in Figure 18. Also included are the p-v relationships for the increased brake volume and increased brake gain test conditions.

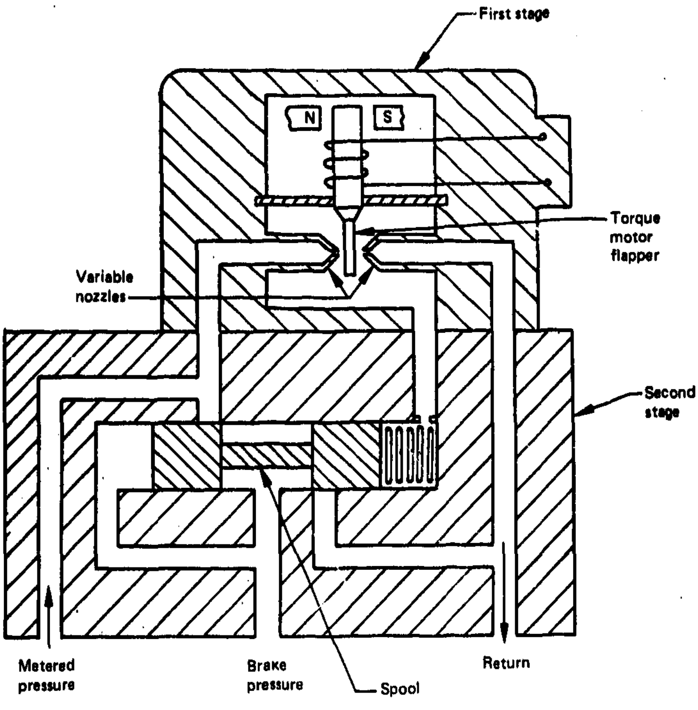

Figure 14.—Hydro-Aire Mark III Antiskid Servo Valve

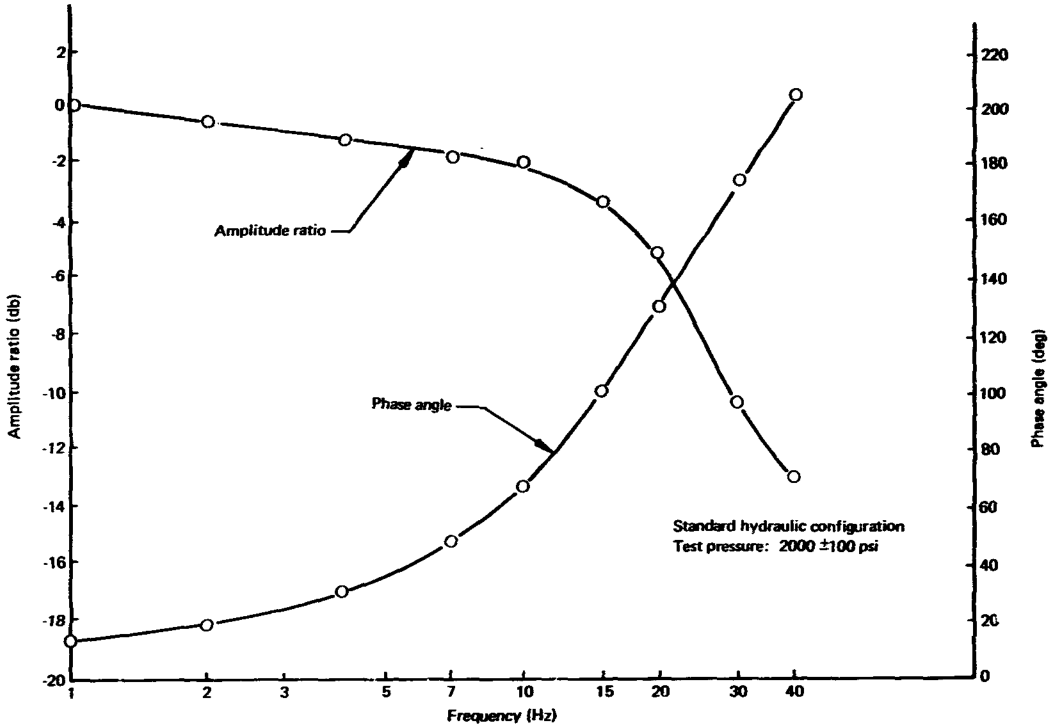

Figure 15.—737 Brake Hydraulic System Frequency Response

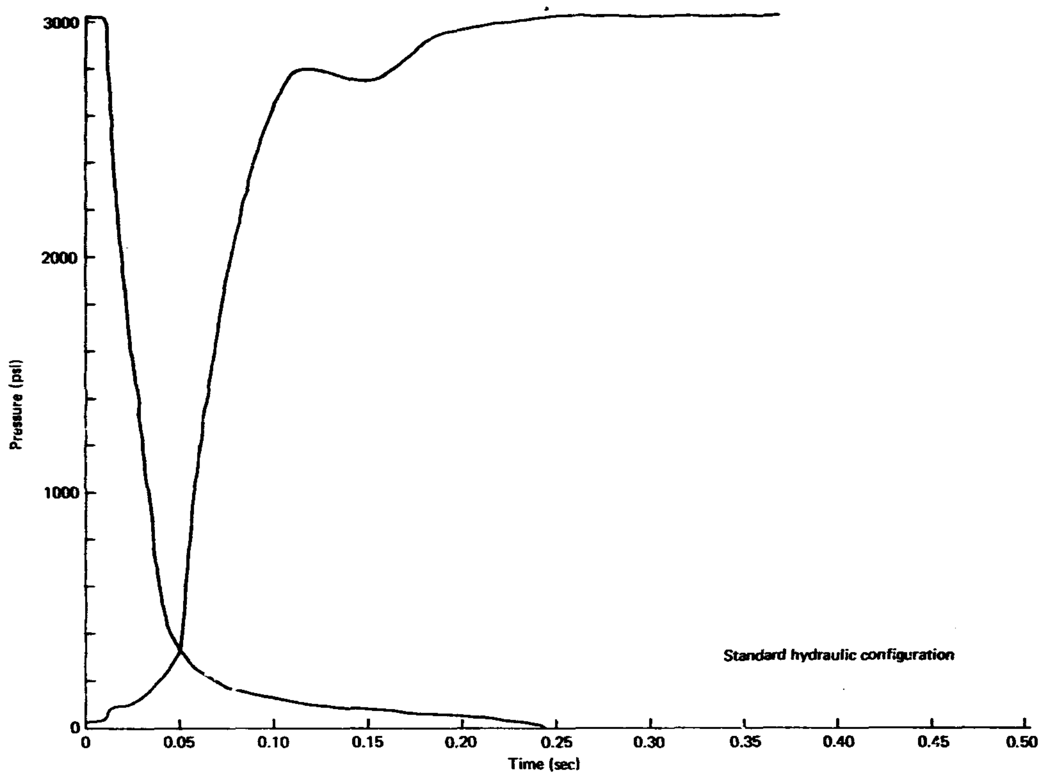

Figure 16.—737 Brake Hydraulic System Step Response

Table 5.—737 Frequency Response Data

Test condition	Test pressure (psi)(±psi)	Resonance point frequency or -3db frequency (Hz)	Gain at resonance or -3 db (db)	Phase angle at resonance or -3 db (deg)	Frequency at 90° phase angle (Hz)
Standard	2000 100	14	-3.0	93.7	14.3
	200	14	-3.0	98.5	12.7
	1000 100	18	-3.0	124.5	13.0
	200	14	-3.0	111.7	11.2
a. Decrease line diameter	2000 100	16	-3.0	137	11.2
	200	15.5	-3.0	140	10.8
	1000 100	16	-3.0	164	9.9
	200	8	+0.8	73.7	9.7
b. Increase line	2000 100	9	-3.0	85	9.5
	200	9	-3.0	84	9.7
	1000 100	10	-3.0	96	9.4
	200	9	-3.0	89	9.1
c. Move dynamic breakpoint out 150% of nominal	2000 100	12	-3.0	66.2	17.2
	200	12	-3.0	72.2	15.5
	1000 100	17	-3.0	97	15.7
	200	14	-3.0	97.4	13.8
d. Move dynamic breakpoint in 50% of nominal	2000 100	15	-3.0	131.5	10.5
	200	15	-3.0	134.5	10.5
	1000 100	15	-3.0	144.5	9.3
	200	14	-3.0	142.2	9.1
e. Restriction*					

*Test not run

Table 6.—737 Step Response Data

Test condition	Pressure step change	Delay response time (sec)		Response time to 80% of pressure change (sec)		Percentage pressure overshoot of step change	
		Pressure increase	Pressure decrease	Pressure increase	Pressure decrease	Pressure increase	Pressure decrease
Standard configuration	0-3000	0.025	0.010	0.090	0.040	0	0
	0-2700	.035	.010	.090	.037	8.9	0
	0-1500	.042	.010	.092	.042	9.3	0
	600-3000	.010	.010	.042	.032	0	6.3
	600-2700	.007	.010	.037	.035	0	7.1
a. Decrease line diameter	0-3000	.060	.012	.105	.040	0	0
	0-2700	.070	.010	.117	.040	5.5	0
	0-1500	.085	.010	.132	.045	12.0	0
	600-3000	.010	.010	.042	.037	0	3.8
	600-2700	.010	.010	.042	.035	2.9	5.7
b. Increase line diameter	0-3000	.042	.010	.127	.060	0	0
	0-2700	.050	.010	.142	.057	5.5	0
	0-1500	.050	.010	.140	.055	8.0	0
	600-3000	.010	.010	.070	.045	0	6.3
	600-2700	.010	.010	.072	.042	4.3	8.6
c. Move dynamic breakpoint out 150% of nominal	0-3000	.050	.007	.092	.030	0	0
	0-2700	.050	.007	.095	.032	5.5	0
	0-1500	.055	.010	.100	.035	10.0	0
	600-3000	.010	.007	.035	.030	0	0
	600-2700	.007	.007	.037	.027	0	0
d. Move dynamic breakpoint in 50% of nominal	0-3000	.080	.015	.135	.045	0	0
	0-2700	.080	.012	.142	.045	8.9	0
	0-1500	.105	.010	.160	.045	12.0	0
	600-3000	.015	.015	.050	.035	0	10.0
	600-2700	.012	.012	.047	.035	2.9	10.0
e. Insert 20% return line restriction	0-3000	.050	.010	.100	.037	0	0
	0-2700	.050	.010	.100	.037	5.5	0
	0-1500	.060	.010	.105	.042	4.0	0
	600-3000	.007	.010	.040	.032	0	5.0
	600-2700	.007	.010	.045	.030	0	7.1

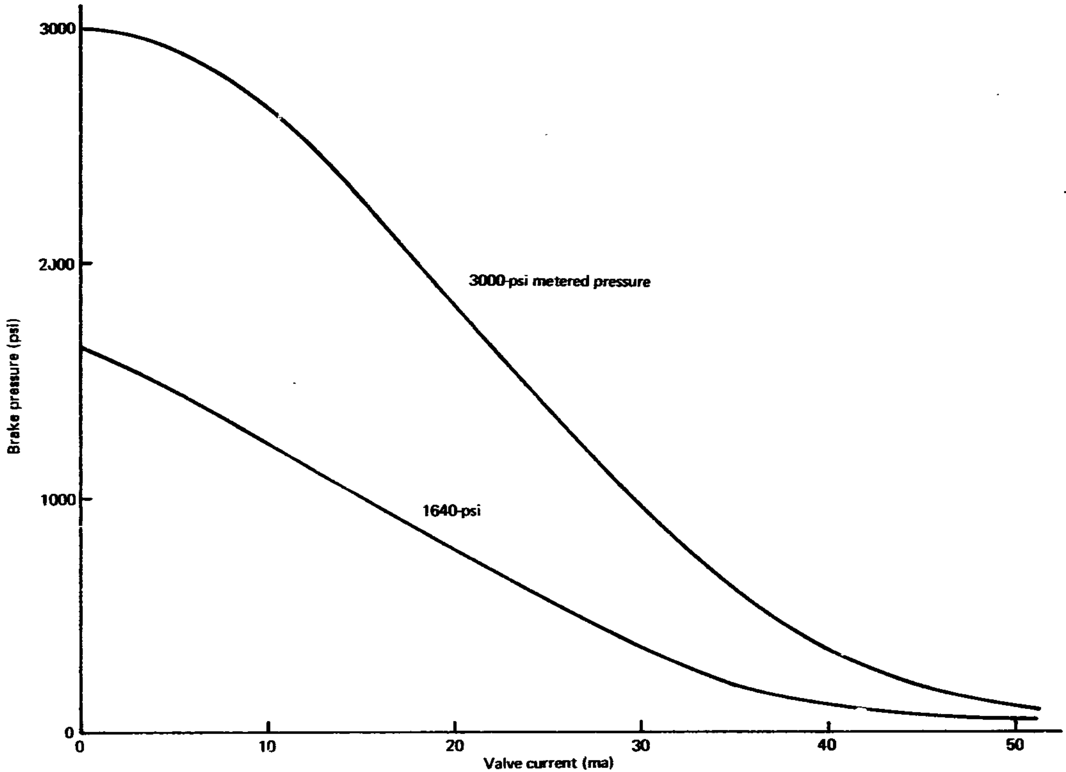

Figure 17.—737 Antiskid Valve Pressure-Current Characteristics

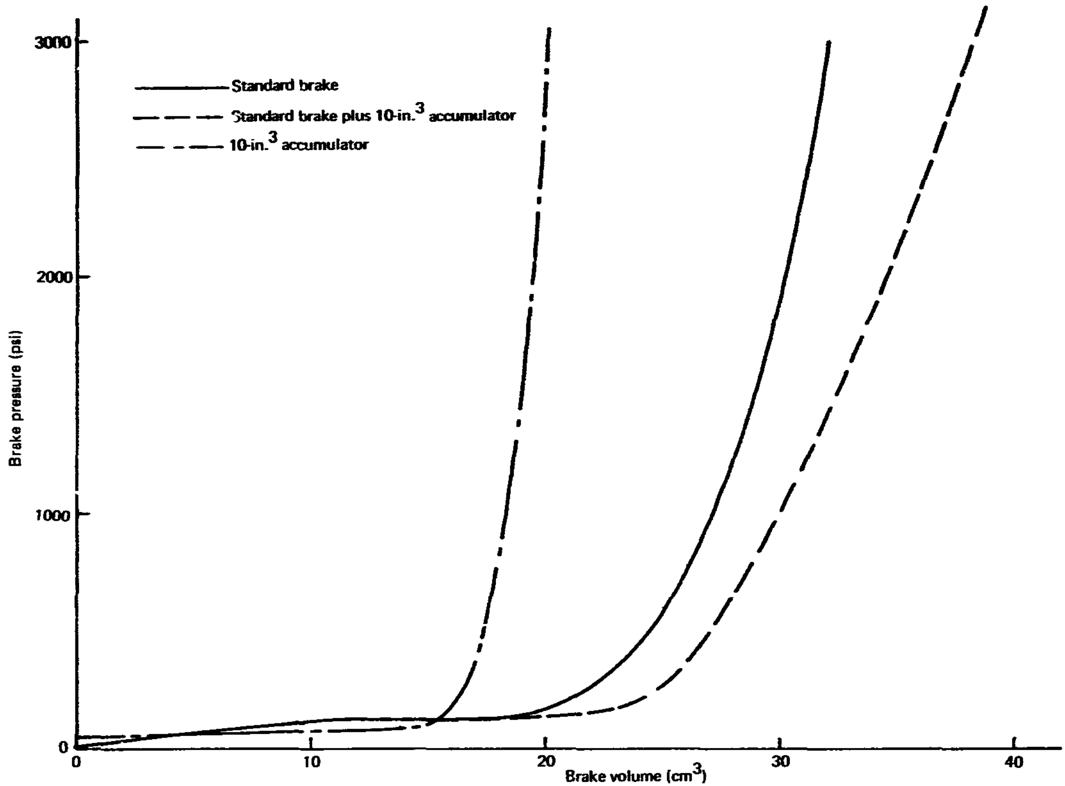

Figure 18.—737 Brake System Pressure-Volume Characteristics

SECTION V

BOEING 747 BRAKE CONTROL SYSTEM DESCRIPTION AND SYSTEM CHARACTERISTICS

The 747 brake control system contains four basic elements: wheel speed transducers, antiskid control system, hydraulic system, and brakes.

The brake hydraulic system mockup is pictured in Figure 19. Line lengths, diameters, bends, materials, and the general layout have been accurately reproduced in the mockup. Figure 20 is a schematic of the 747 brake hydraulics. Table 7 in conjunction with this figure defines the significant hydraulic system information.

1. SYSTEM DESCRIPTION

a. WHEEL SPEED TRANSDUCER

The 747 wheel speed transducer, pictured in Figure 21, is a self-contained device mounted in the axle. It has two functional parts, a rotor and a stator, each of which is made of ferrous material and has 200 teeth. A magnetic field is established by supplying current to the stator coil. As the rotor turns, the alternating alignment and misalignment of the teeth in the rotor and the stator vary the reluctance in the magnetic current. This results in an alternation in the supply current, which generates an AC frequency proportional to wheel speed.

b. ANTISKID CONTROL SYSTEM

The Boeing 747 incorporates the Mark III skid system manufactured by Hydro-Aire for brake control. The system is represented by the functional block diagram in Figure 22. The wheel speed transducers in each braked wheel provide the instantaneous wheel speed information required by the control circuit. The transducer AC signal is converted to a DC voltage in the frequency converter block. This DC voltage is directly proportional to the actual wheel speed.

A reference aircraft velocity is provided by the reference velocity and reference deceleration functions shown in the block diagram. At touchdown, the velocity comparator develops a negative error signal, which forces the velocity reference to increase until the error signal ceases. In this manner, the reference velocity is initialized at touchdown for the braking condition to follow. During the recovery from a skid, the wheel spinup action results in a reinitialization of the reference velocity.

The reference deceleration function provides an output derived from the gradually changing component of wheel speed; thus, the output is proportional to wheel deceleration. The reference deceleration is an input to the reference velocity function; it modifies the rate of velocity decay as a function of the prevailing wheel condition.

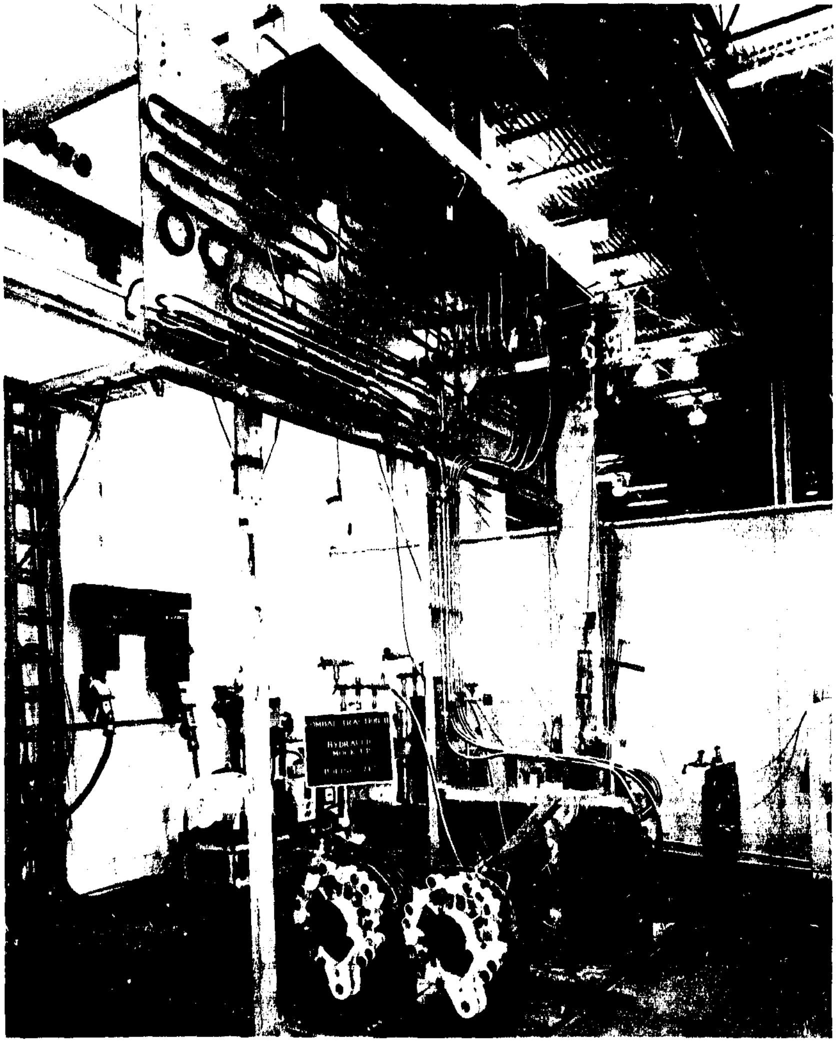

Figure 19.—747 Brake Hydraulic System Mockup

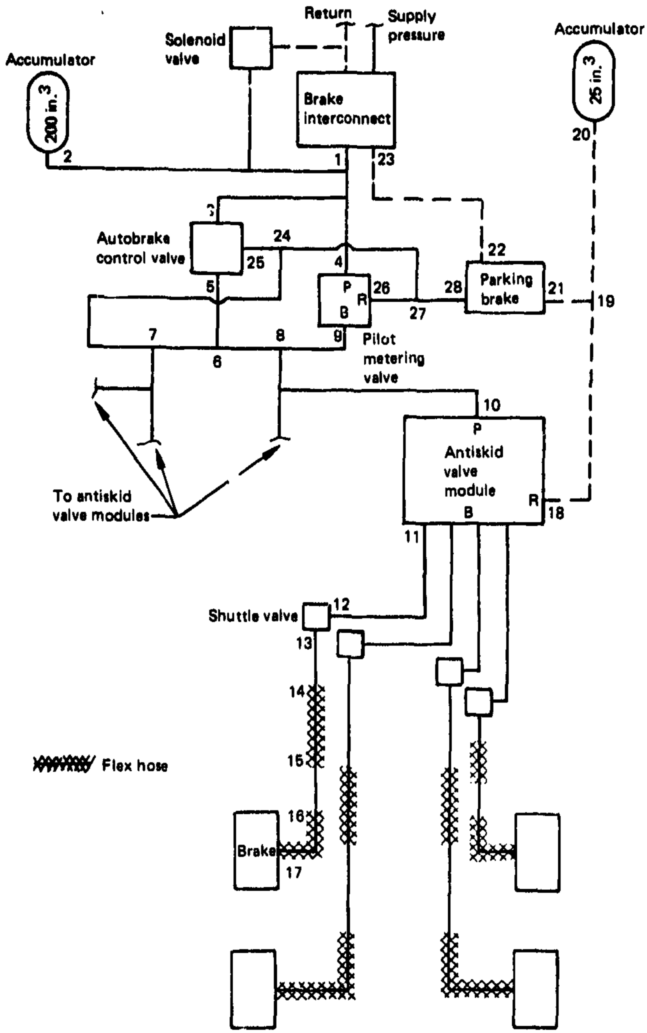

Figure 20.—747 Brake Hydraulic System Schematic

Table 7.—747 Brake Hydraulic System Mockup

Description	Index point (from-to)	Line size	Line length (in.)
Accumulator line	1-2	8S26	18
Autobrake supply line	1-3	8S26	60
Pilot metering valve supply	1-4	8S26	216
Antiskid supply line	9-8	8S26	36
	8-10	8S26	156
	8-6	8S26	192
	6-7	8S26	192
	7-24	10S33	168
	24-25	6S20	12
	24-27	10S33	6
	27-28	10S33	48
	27-26	10S33	168
Brake supply line (typical)	11-12	6S20	8
	13-14	6S20	132
	14-15	1/4 hose	54
	15-16	6S20	60
	16-17	1/4 hose	126
Return line (typical)	18-19	10S33	96
	19-20	10S33	24
	19-21	10S33	156
	22-23	10A35	30

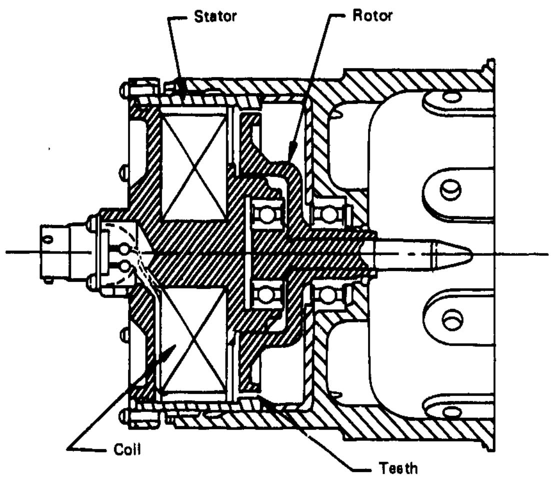

Figure 21.—747 Hydro-Aire Mark III Antiskid Wheel Speed Transducer

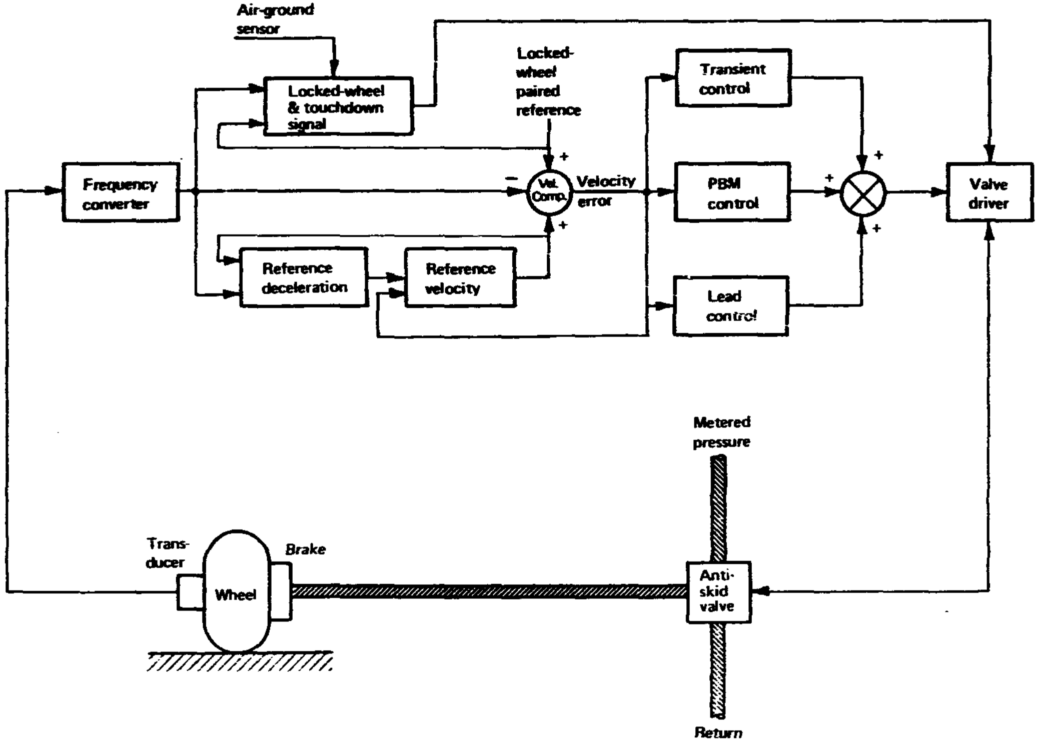

Figure 22.—747 Mark III Antiskid System Block Diagram

The reference deceleration function provides an output derived from the gradually changing component of wheel speed; thus, the output is proportional to wheel deceleration. The reference deceleration is an input to the reference velocity function; it modifies the rate of velocity decay as a function of the prevailing wheel condition.

The signals from the frequency converter and the reference velocity function are summed in the velocity comparator. The output of the comparator is a velocity error signal that drives the control circuit, resulting in pressure modulation at the brake. The control circuit, consisting of the pressure bias modulation (PBM), transient control, and lead circuits, is responsible for normal system control.

The PBM is the time integral of velocity error and, in comparison to the transient control, is slower to respond to error signals. The PBM determines the brake pressure when the wheel is not skidding. It reduces the pressure level during a skid and gradually increases it after the skid. In this manner, the system adapts to varying runway conditions and also seeks to keep braking at the highest possible level.

The transient control is characterized by a fixed gain and threshold. Its input is the velocity error coming from the velocity comparator and thus is a proportional control when the appropriate threshold has been exceeded. The primary purpose of the transient control is to reduce pressure quickly to provide wheel recovery from a skid.

The remaining control element, lead, is in the form of a velocity error rate, which is coupled into the summing amplifier. Since it represents the rate of velocity change, a differentiation, it provides a dynamic lead function that anticipates and initiates the brake pressure modulation to help control skids. The lead control is used to quicken the system response, thus improving efficiency. Appropriate use of lead control can also improve overall system strut damping by way of dynamic compensation.

The remaining system components include the summing amplifier and valve driver. Signals from the PBM, transient, and lead controls are summed by the summing amplifier, and this output becomes the driving function for the valve driver. The valve driver provides current to the antiskid valve proportional to the voltage from the summing amplifier.

c. TOUCHDOWN AND LOCKED-WHEEL PROTECTION

In addition to normal skid control, touchdown protection on the 747 is provided by the landing gear logic system. Proximity switches (two per truck) sense when the airplane is on the ground by noting that the trucks are out of tilt. While in the air, the logic system supplies a brake release signal to the antiskid valve. Once on the ground with at least two trucks out of tilt, the signal is removed, allowing normal antiskid operation to occur. Wheel spinup will override the touchdown protection signal, permitting normal braking if the air-ground sensing switches are not activated upon touchdown.

Locked-wheel protection is provided for each wheel having antiskid protection. Four sets of four-wheel groups are used. Both front and rear left outboard wing gear wheels are grouped with the right front and rear inboard body gear wheels. The same pattern is used to combine the remaining three locked-wheel groups.

Locked-wheel protection operates through the normal control path of the system. The system is implemented by generating a locked-wheel reference, which is a fixed percentage of the highest reference velocity of the locked-wheel group. When the reference velocity for a particular wheel is less than the locked-wheel reference (because of a wheel lockup), the locked-wheel reference is used as the reference input to the velocity comparator. This ensures that an error signal is developed and the brake released.

d. BRAKE HYDRAULIC SYSTEM

The 747 brake hydraulic system employs two pilot metering valves and four antiskid valve modules as the basic system components. The system receives 3000-psi pressure from the ships primary hydraulic system. This pressure is supplied to the pilot metering valve, which is a pressure control valve. The metering valve pressure, which is the antiskid valve supply pressure, is regulated by a manual input signal from the pilot. Depending on the input, the pilot can meter from zero to 3000 psi to the antiskid valve. The metered pressure is the maximum attainable output pressure of the antiskid valve. The actual output of the antiskid valve is controlled by the electrical signal from the skid control box.

The Hydro-Aire Mark III antiskid valve is shown in Figure 23. It is a two-stage valve with a flapper and nozzle first stage and spool and sleeve second stage. A permanent magnet torque motor in the first stage operates the flapper. The hydraulic bridge built around the flapper consists of two fixed and two variable nozzles. The application of an electrical signal to the torque motor from the skid control box causes the flapper to move from the neutral position (maximum pressure). Movement of the flapper unbalances the bridge, with a resultant pressure differential applied to the second stage spool. Movement of the flapper from the relaxed position serves to reduce pilot metered pressure to the brake. The forces on the spool work to position it until an equilibrium position is reached. The output of the antiskid valve provides the control pressure to the brakes.

e. BRAKES

The brakes used during the sensitivity study were manufactured by Bendix. The modulation of pressure from the antiskid valve causes compression or relaxation of the brake stack. Such action results in a controlled braking action.

2. BRAKE SYSTEM CHARACTERISTICS

As part of the sensitivity study, the characteristics of the brake system were measured. The dynamic response of the standard 747 hydraulic system is shown in Figures 24 and 25. Figure 24 plots a typical frequency response of the system, while Figure 25 represents step response. Tables 8 and 9 compile the dynamic response data resulting from hydraulic system changes.

The pressure-current characteristics of the 747 antiskid valve are shown in Figure 26. The effect of varying the pilot metered pressure is depicted by the different curves.

The pressure-volume relationship of the standard 747 brake is shown in Figure 27. Also shown are the p-v characteristics for the increased brake volume and increased brake gain test conditions.

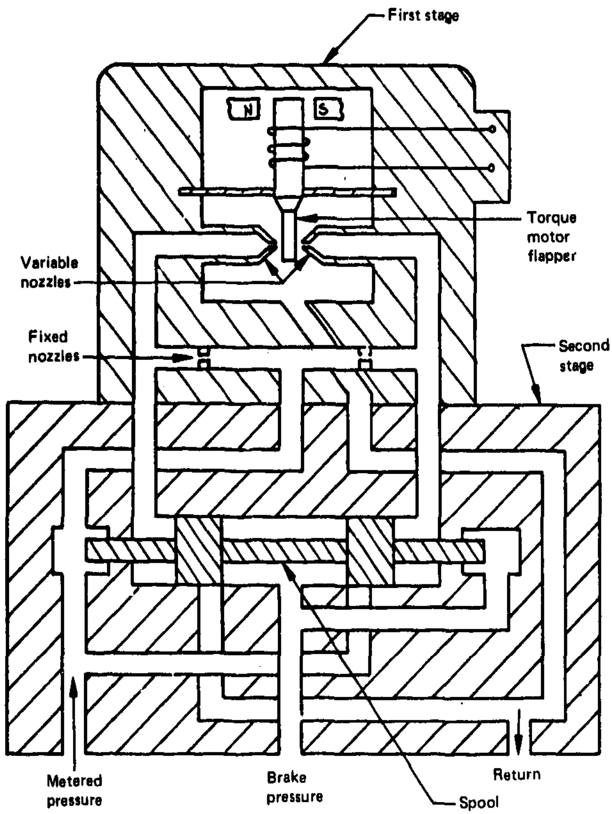

Figure 23.—747 Hydro-Aire Mark III Antiskid Servo Valve

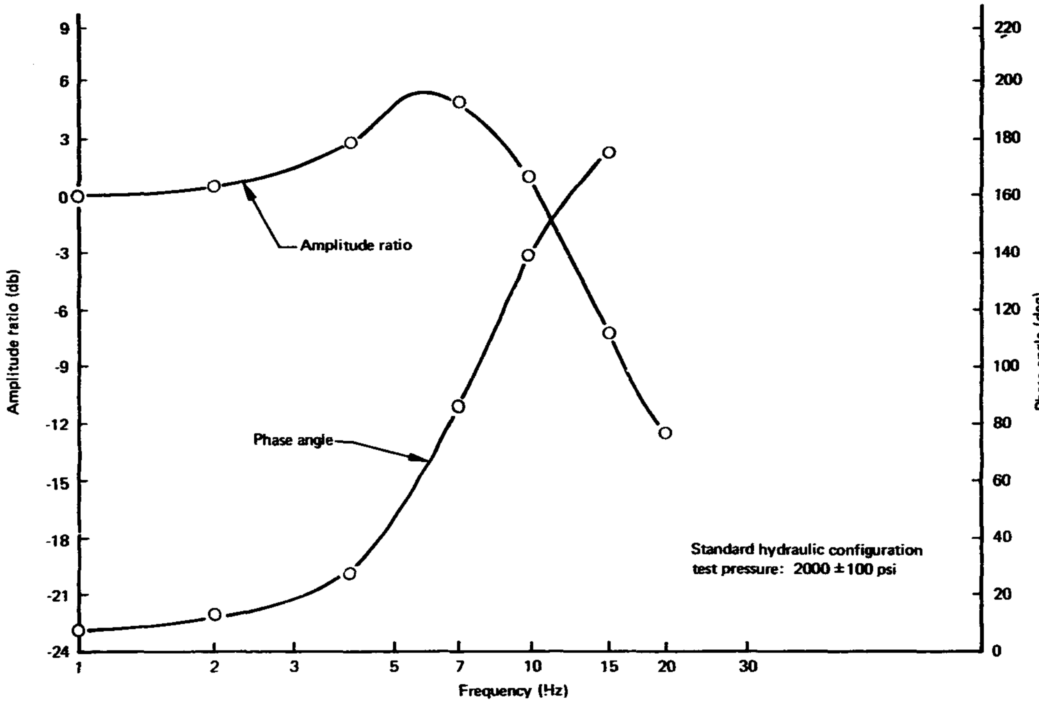

Figure 24.—747 Brake Hydraulic System Frequency Response

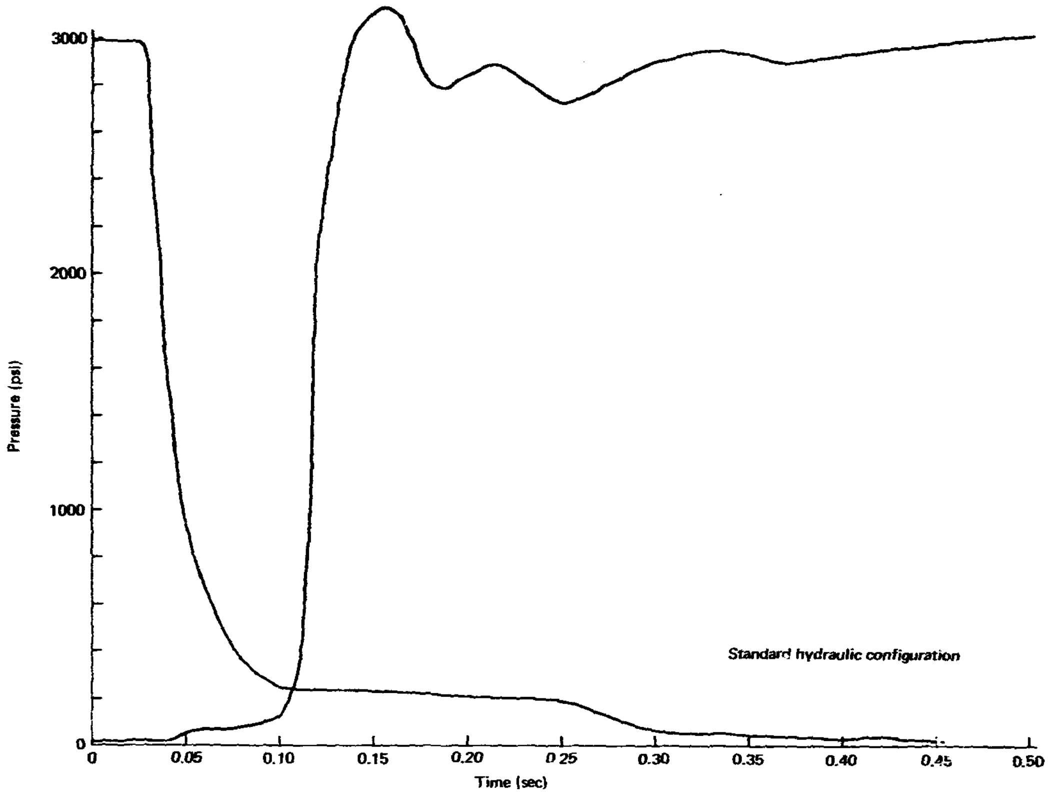

Figure 25.–747 Brake Hydraulic System Step Response

Table 8.—747 Frequency Response Data

Test condition	Test pressure (psi) (±psi)	Resonance point frequency or -3 db frequency (Hz)	Gain at resonance or -3 db (db)	Phase angle at resonance or -3 db (deg)	Frequency at 90° phase angle (Hz)
Standard	2000 100	6	5.4	61	7.2
	200	6	4.7	55	7.8
	1000 100	5	4.7	60	6.0
	200	6	4.3	83	6.3
a. Decrease line diameter *					
b. Increase line	2000 100	6	5.3	70	6.6
	200	6	4.3	62	7.1
	1000 100	5	4.7	71	5.6
	200	5	3.3	59	6.2
c. Move dynamic breakpoint out 150% of nominal	2000 100	7	6.1	68	7.9
	200	8	5.5	85	8.2
	1000 100	6	5.3	68	6.9
	200	7	4.5	87	7.1
d. Move dynamic breakpoint in 50% of nominal	2000 100	6	5.9	75	6.5
	200	6	5.2	69	6.8
	1000 100	5	4.7	78	5.4
	200	5	4.2	74	5.6
e. Restriction	2000 100	6	5.8	63	7.0
	200	6	5.3	59	7.4
	1000 100	5	4.7	64	5.9
	200	6	4.1	89	6.0

* Test not run

Table 9.—747 Step Response Data

Test condition	Pressure step change	Delay response time (sec)		Response time to 80% of pressure change (sec)		Percentage pressure overshoot of step change	
		Pressure increase	Pressure decrease	Pressure increase	Pressure decrease	Pressure increase	Pressure decrease
Standard	0-3000	0.085	0.025	0.125	0.061	2.7	0
	0-2700	.100	.012	.132	.055	3.3	0
	0-1500	.085	.017	.197	.085	20.0	0
	600-3000	.015	.030	.050	.060	2.5	11.3
	600-2700	.015	.017	.050	.045	17.1	11.4
a. Decrease line diameter*							
b. Increase line diameter	0-3000	.050	.030	.120	.060	0	0
	0-2700	.050	.015	.115	.050	7.4	0
	0-1500	.080	.015	.160	.060	20.0	0
	600-3000	.015	.030	.045	.060	2.5	15.0
	600-2700	.015	.015	.050	.045	14.3	17.1
c. Move dynamic breakpoint out 150% of nominal	0-3000	.050	.027	.090	.065	4.0	0
	0-2700	.080	.015	.115	.040	15.6	0
	0-1500	.113	.030	.170	.050	24.0	0
	600-3000	.015	.015	.030	.055	12.5	15.0
	600-2700	015	.015	.045	.040	20.0	17.1
d. Move dynamic breakpoint in 50% of nominal	0-3000	.090	.030	.130	.065	8.0	0
	0-2700	.050	.020	.085	.055	15.6	0
	0-1500	.150	.025	.190	.055	20.0	0
	600-3000	.025	.040	.052	.065	12.5	12.5
	600-2700	.025	.020	.055	.045	20.0	17.1
e. Insert 20% return line restriction	0-3000	.080	.030	.100	.067	4.0	0
	0-2700	.115	.020	.135	.052	15.6	0
	0-1500	.165	.020	.180	.070	24.0	0
	600-3000	.020	.035	.050	.060	5.0	15.0
	600-2700	.020	.020	.050	.045	20.0	17.1

*Test not run.

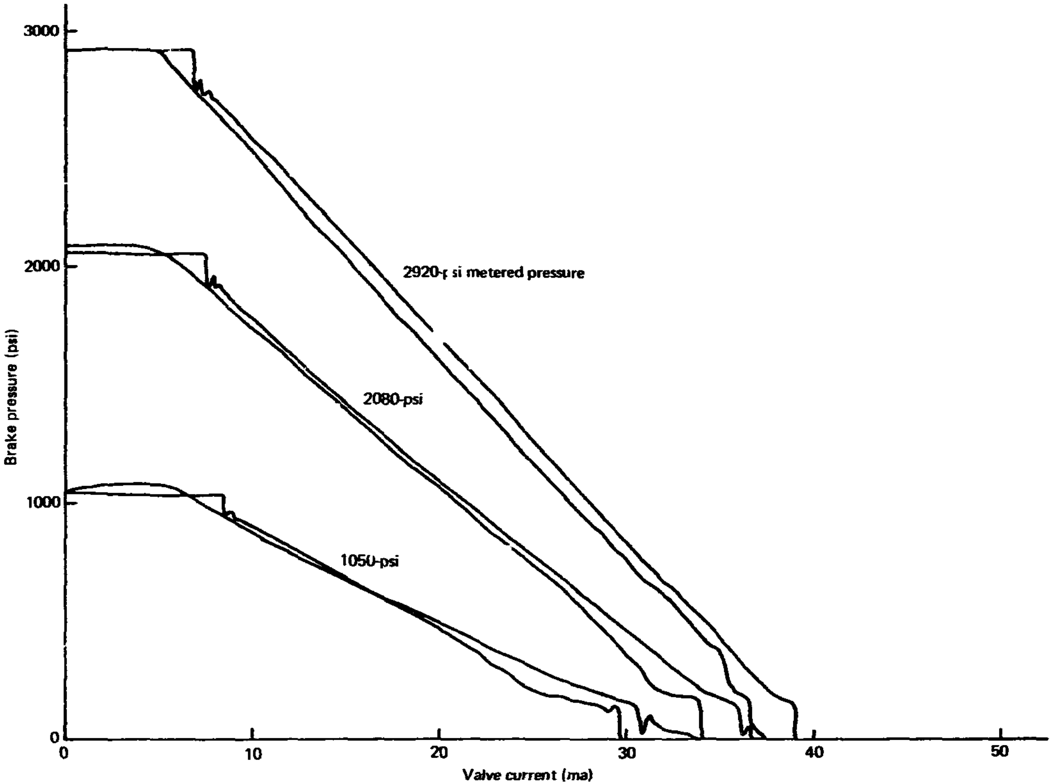

Figure 26.—747 Antiskid Valve Pressure-Current Characteristics

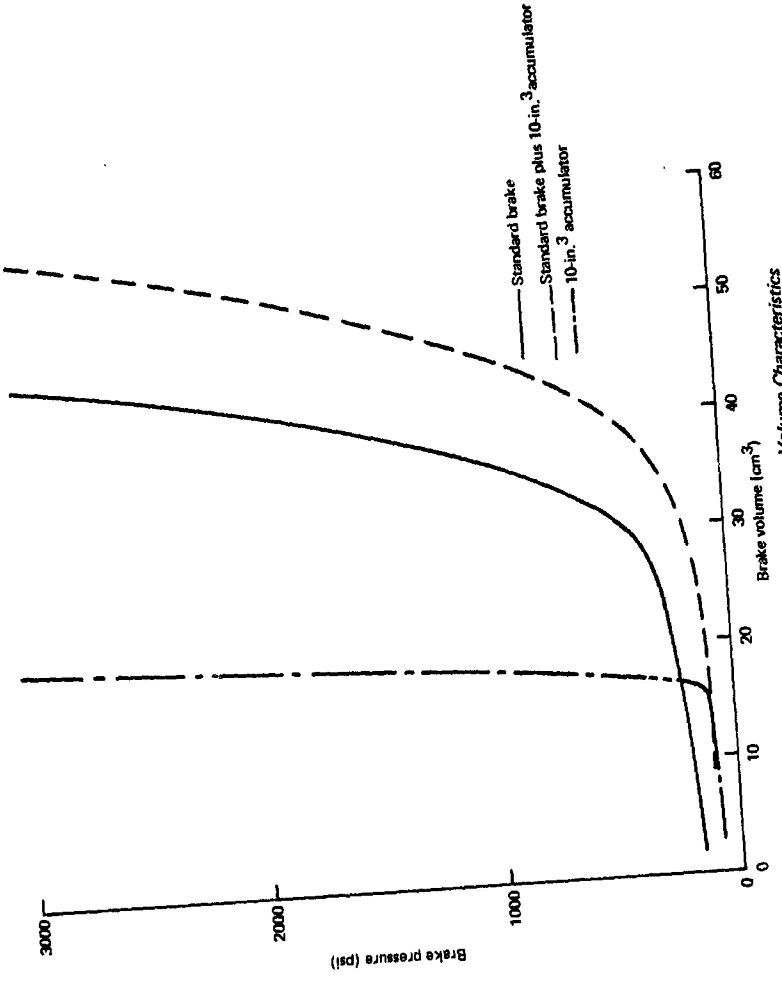

Figure 27.—747 Brake System Pressure-Volume Characteristics

SECTION VI
C-141 BRAKE CONTROL SYSTEM DESCRIPTION AND SYSTEM CHARACTERISTICS

The C-141 brake control system includes the brake hydraulic system, antiskid control system, wheel speed transducers, and brakes. The brake hydraulic system mockup used during the sensitivity study is pictured in Figure 28. A schematic identifying the mockup components is given in Figure 29. This figure and Table 10 specify the line dimensions and materials used in the mockup.

1. SYSTEMS DESCRIPTION

a. WHEEL SPEED TRANSDUCER

The C-141 wheel speed transducer, as pictured in Figure 30, provides the antiskid control system with instantaneous wheel speed information. The device is self-contained; a unit is mounted in the axle of each wheel. The transducer is a simple AC generator providing six cycles per wheel revolution. The signal is amplitude-modulated in addition to the frequency modulation typical of wheel speed transducers. Both the frequency and amplitude are proportional to wheel speed.

b. ANTISKID CONTROL SYSTEM

The C-141 antiskid control system, designed by Bendix, provides individual skid protection for the eight main wheels of the aircraft. The Bendix system is represented by Figure 31 in a simplified form.

The axle-mounted wheel speed transducer provides instantaneous wheel speed information to the control circuit. The transducer signal enters the circuit at the rate sensing block, where it is conditioned and rectified to produce a DC voltage. The DC voltage is proportional to wheel speed. The DC wheel speed signal is differentiated, yielding the wheel deceleration used for primary antiskid control. The wheel deceleration is compared to a preset value. When the fixed decleration level is exceeded, the degree of rate circuit supplies a signal to the antiskid valve, which results in brake release. Two levels of control are provided by circuit logic. The first level is initiated when a small deceleration rate occurs. This causes the rate-sensing circuit to activate the Step 1 circuit, which energizes the Step 1 solenoid of the control valve. The result of this action is a moderate brake release. For larger decelerations, the Step 2 circuit is activated, energizing the Step 2 solenoid and resulting in fast brake release.

As the wheel spins up and the actual wheel deceleration becomes less than the control thresholds, the Step 1 and Step 2 solenoids are deenergized. Reapplication of pressure is controlled by the antiskid valve and not the control circuit. A schematic of the antiskid valve is shown in Figure 32.

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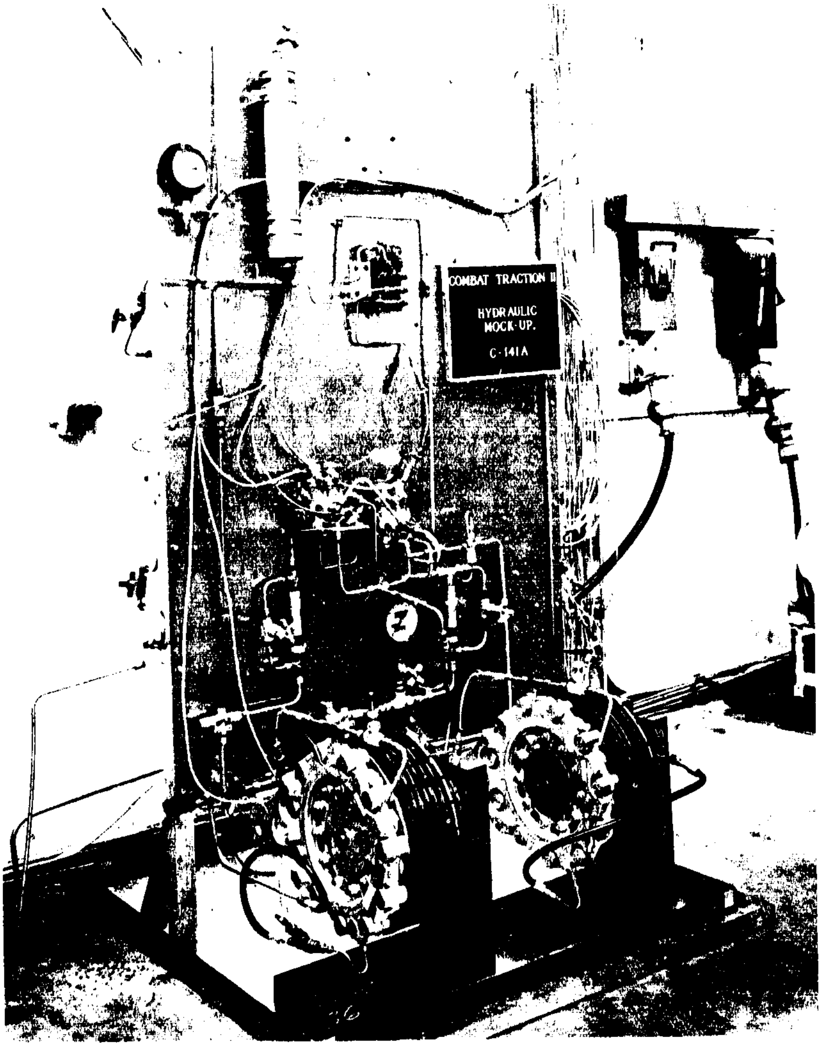

Figure 28.—C-141 Brake Hydraulic System Mockup

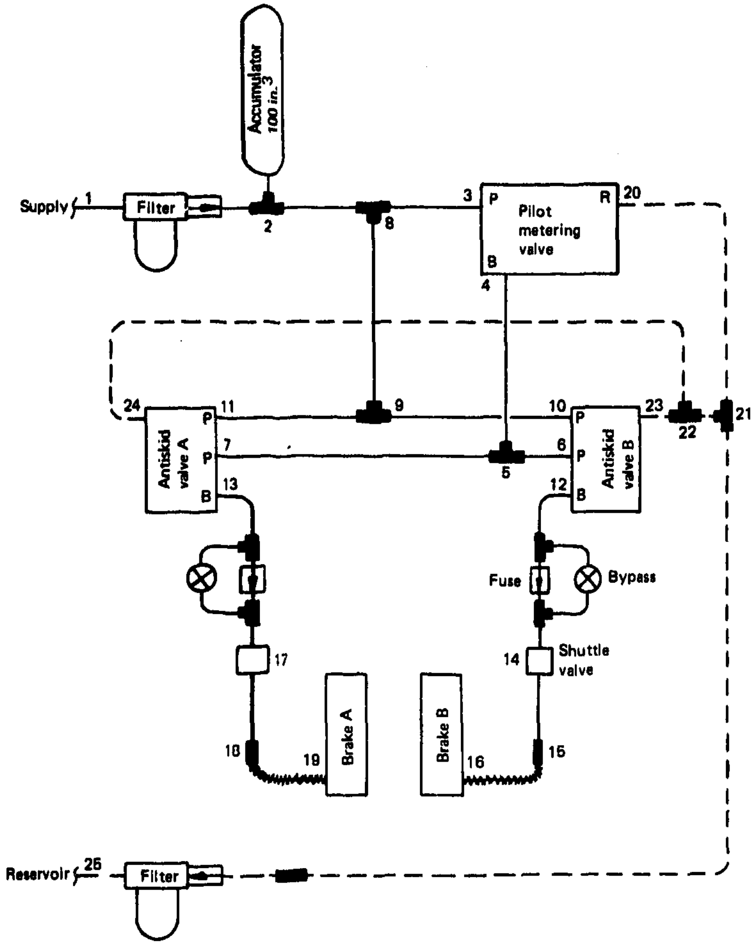

Figure 29.—C-141 Brake Hydraulic System Schematic

Table 10.—C-141 Brake Hydraulic System Mockup

Description	Index point (from-to)	Line size	Line length (in.)
Common supply line	1-2 2-3	4S20 4S20	50 12
Common metered pressure line	4-5	4S20	807
Common No. 2 pressure supply line	8-9	8S35	120
A-system metered pressure line	5-7	4S20	10
A-system brake line	13-17 17-18 18-19	6S28 8S35 3/8 hose	23.5 336 36
A-system No. 2 pressure supply line	9-11	6S28	12
B-system metered pressure line	5-6	4S20	10
B-system brake line	12-14 14-15 15-16	6S28 8S35 3/8 hose	23.5 336 36
B-system No. 2 pressure supply line	9-10	6S28	8
Retur line	20-21 22-23 22-24 21-22 21-25	4A20 6A28 6A28 10A42 10A42	56 9 9 4 120

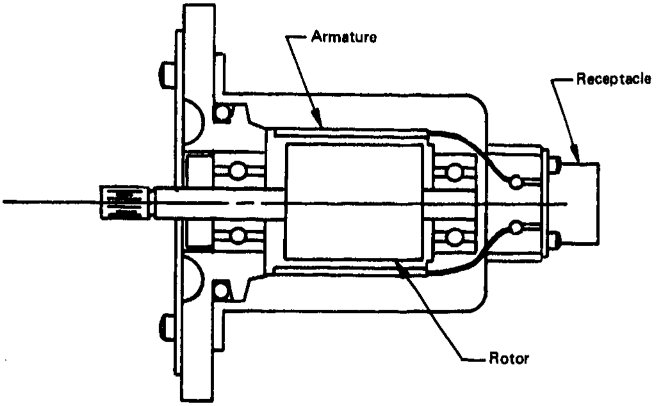

Figure 30.—C-141 Wheel Speed Transducer

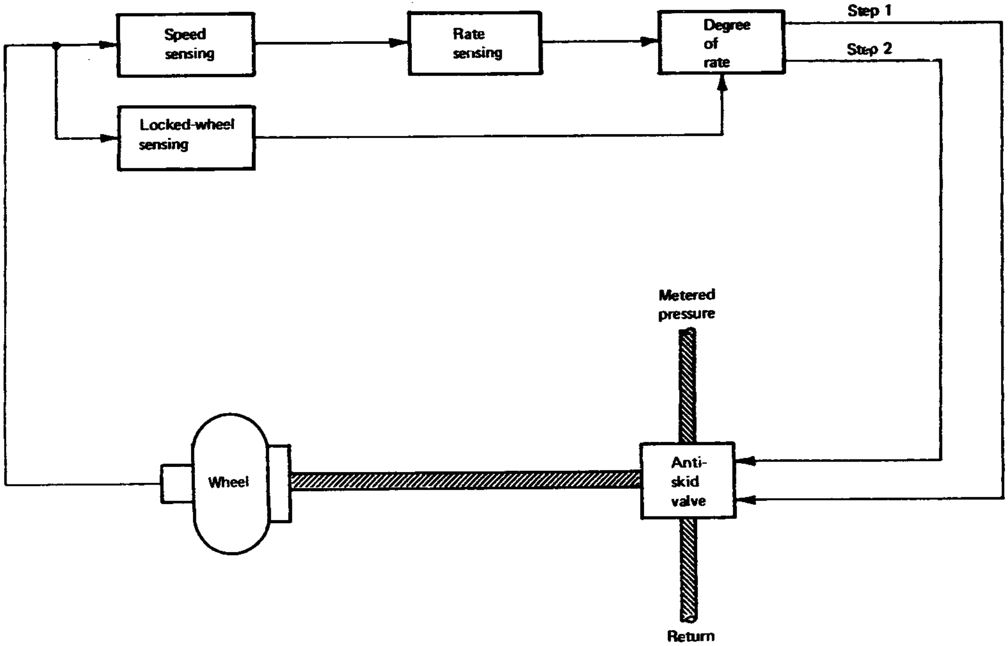

Figure 31.—C-141 Antiskid System Block Diagram

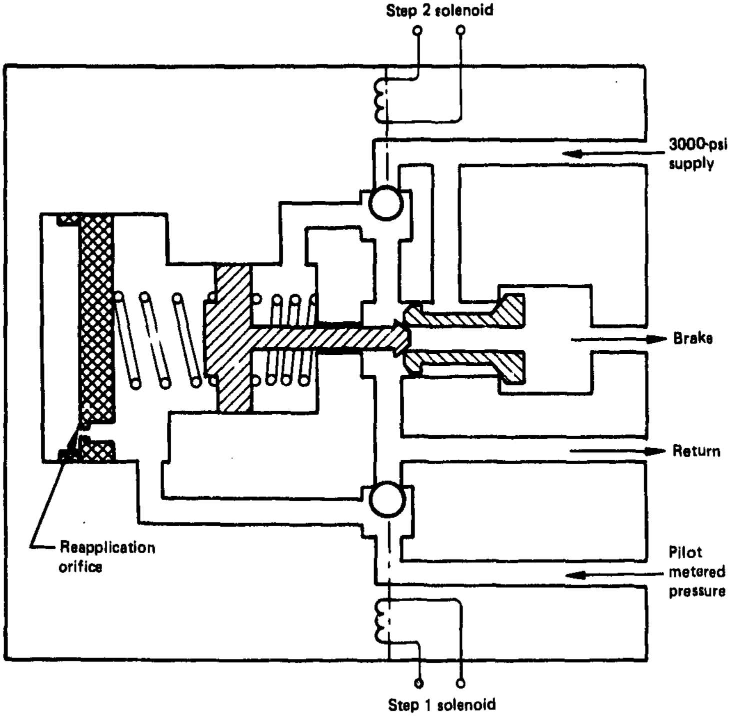

Figure 32.—C-141 Antiskid Control Valve Schematic (Shown Deenergized; High Brake Pressure)

c. TOUCHDOWN AND LOCKED-WHEEL PROTECTION

The locked-wheel protection consists of an arming circuit and a sensing circuit. The sensing circuit determines if the wheel is turning at a rate faster than 85 rpm (15 mph). When the wheel is rotating faster than this speed, a signal is supplied to the arming circuit; if not, a signal is produced, if the system is armed, to activate the Step 1 and 2 solenoids.

For arming, the four forward wheels and the four aft wheels are paired. The system is armed when any of the four wheels is rotating faster than 85 rpm. A time delay circuit prevents disarming for momentary lockup of all four wheels. Touchdown protection is provided by arming the system in the air using squat switch logic.

d. BRAKE HYDRAULIC SYSTEM

The brake hydraulic system has two major components: a pilot metering valve and an antiskid valve. The system is supplied with 3000-psi pressure from the ships hydraulic system to the pilot metering valve. The valve is a pressure control device with an output pressure limited to 2200 psi. The aircraft has right and left metering valves allowing the pilot to employ differential braking. The pilot metered pressure, which is an input to the antiskid valve, is the maximum available pressure at the brake. The actual pressure at the brake is controlled by the electrical signal from the skid control box and antiskid valve.

Unlike the more advanced systems, which employ pressure control valves, the C-141 antiskid valve is a simple solenoid valve. In addition to the control pressure from the pilot metering valve, the antiskid valve has a second supply that provides 3000-psi pressure and serves as the main hydraulic supply to the brakes. The 3000-psi is reduced to a maximum output pressure of 2200 psi by a force balance within the antiskid valve. The control box supplies a signal to the antiskid valve, resulting in a pressure dump to zero pressure. The actual dump rate is determined by an orifice and by two solenoids, which are termed Step 1 and Step 2 solenoids.

Activation of Step 1 allows the control pressure to dump through an orifice. This results in a moderate dump rate. Activation of the Step 2 solenoid opens the brake and control pressures directly to return, causing a very fast pressure dump. Reapplication of pressure is initiated after both solenoids have been deenergized. The pilot control pressure is then metered through an orifice. The orifice size determines the reapplication pressure rate.

e. BRAKES

The C-141 brakes used in the mockup were six-rotor steel brakes. The modulation of pressure from the antiskid valve causes the brake stack to compress or release. This action results in a controlled braking action.

2. BRAKING SYSTEM CHARACTERISTICS

During the sensitivity study various system and component characteristics were measured. The dynamic response of the standard C-141 hydraulic system is shown in Figure 33. This figure is a representative step response curve for the system. Table 11 compiles the step response data resulting from the hydraulic system changes.

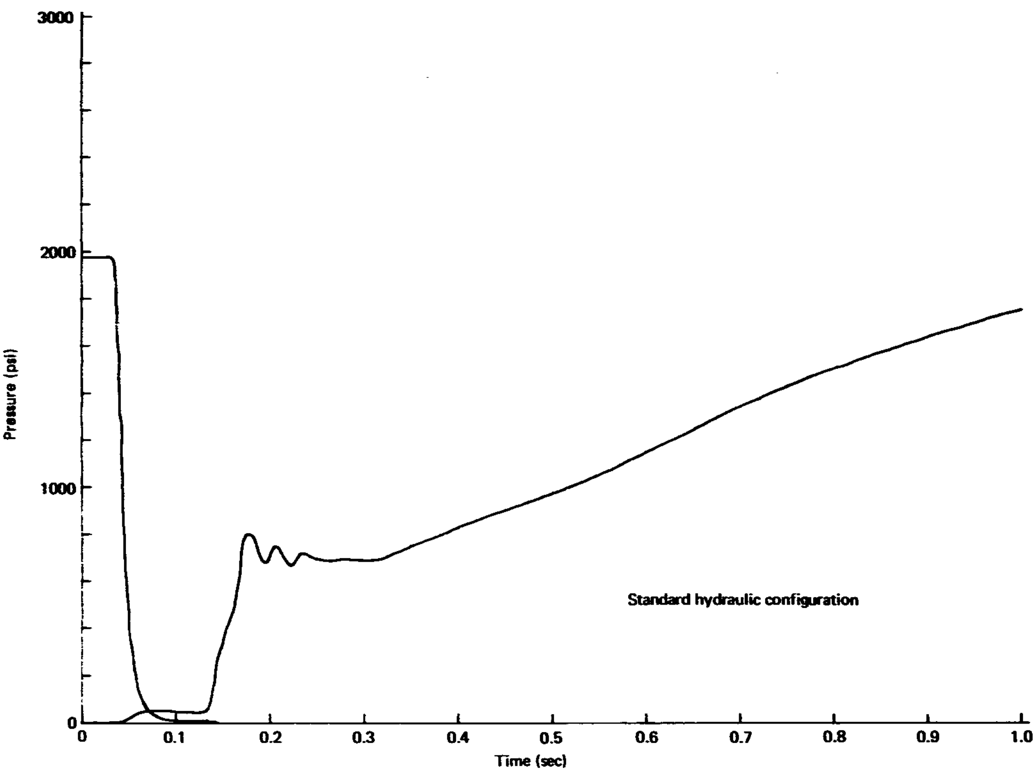

Figure 33.—C-141 Brake Hydraulic System Step Response

Table 11.—C-141 Step Response Data

Test condition	Solenoid activated	Pressure decrease		Pressure increase		
		Delay response time (sec)	Response time to 80% of pressure change (sec)	Delay response time (sec)	Slope (psi/sec)	Level (psi)
Standard	1	0.030	0.227	0.032	1850	310
a. Decreased line diameter	1	.030	.230	.040	2250	300
	1,2	.032	.057	.210	750	1040
b. Increased line diameter	1	.025	.230	.030	2150	300
	1, 2	.025	.067	.225	1050	900
c. Move dynamic breakpoint out 150% of nominal	1	.020	.223	.025	2500	300
	1, 2	.020	.040	.120	1050	800
d. Move dynamic breakpoint in 50% of nominal	1	.035	.230	.035	1670	320
	1, 2	.035	.065	.210	1408	950
e. Insert 20% return line restriction	1	.027	.215	.035	2250	310
	1, 2	.027	.055	.160	1100	840

The frequency response and pressure-current characteristics were not run on this system because of the nature of the antiskid valve.

The pressure-volume characteristics of the standard C-141 brake is shown in Figure 34. Also included are the p-v relationships for the increased brake volume and increased brake gain tests.

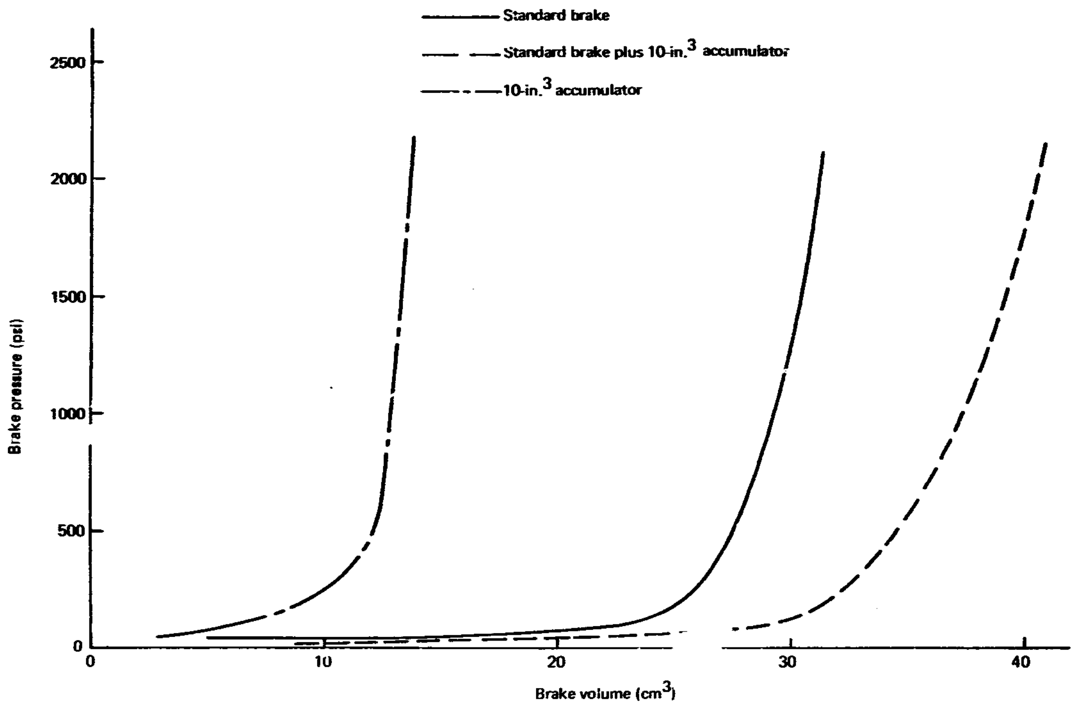

Figure 34.—C-141 Brake System Pressure-Volume Characteristics

SECTION VII

F-4 BRAKE CONTROL SYSTEM DESCRIPTION AND SYSTEM CHARACTERISTICS

The F-4 brake control system consists of four basic elements: wheel speed transducer, antiskid control system, brake hydraulic system, and brakes. The hydraulic mockup used in the sensitivity studies is shown in Figure 35. The mockup was loaned to The Boeing Company by Hydro-Aire for this series of tests. Figure 36 is a detailed schematic of the actual system tested. Table 12 lists the pertinent dimensions and materials used in the hydraulic simulator.

1. SYSTEM DESCRIPTION

a. WHEEL SPEED TRANSDUCER

The F-4 wheel speed transducer provides the antiskid control box with the required instantaneous wheel speed information. The transducer is a two-part device, consisting of a rotor and an electromagnetic sensor. The sensor is mounted in the brake housing and is stationary. The rotor (sensor exciter ring) is mounted on the wheel assembly and contains 90 teeth. The sensor, which consists of a permanent magnetic and coil, creates a magnetic field. As the rotor passes through the field, the alternating alignment and misalignment of the rotor teeth and the sensor vary the reluctance in the magnetic current. This results in an alternating current with frequency proportional to wheel speed.

b. ANTISKID CONTROL SYSTEM

The F-4 Hytrol Mark II skid control system tested is represented in block diagram form by Figure 37. The system requires active wheel speed inputs. This information is provided by a transducer located at each braked wheel. The transducer AC signal is converted to a DC voltage in the control box by the squaring circuit and velocity amplifier. The squaring circuit converts the sinusoidal wheel speed signal of a square wave with frequency proportional to the wheel speed. The velocity amplifier then reduces the square wave to a DC voltage. The level of the DC voltage is a measure of the true wheel speed.

The DC wheel speed is differentiated in the rate amplifier to produce instantaneous wheel deceleration. This deceleration is compared to a fixed threshold value; when the actual wheel deceleration exceeds the threshold, a brake release signal is initiated. The duration and magnitude of the brake release is based on the absolute wheel speed departure. In addition to this proportional control a pressure bias modulation (PBM) circuit provides an extension of the original control signal after the wheel has recovered from a skid. During a skid, the PBM is charged to a level proportional to the duration and magnitude of the skid. After the wheel has recovered from a skid, the PBM discharges ramping pressure on. To ensure that the same brake pressure is not reapplied after a skid. the PBM is charged to a higher value than it had previous to the skid.

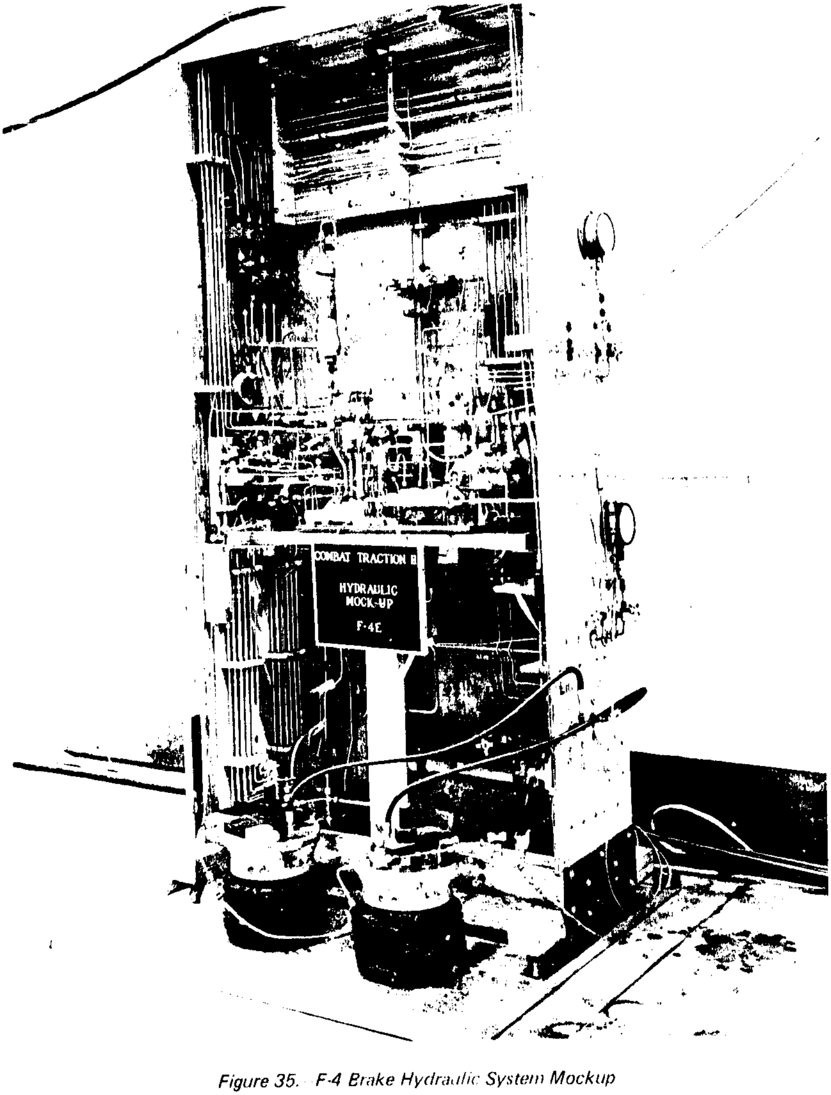

Figure 35. F-4 Brake Hydraulic System Mockup

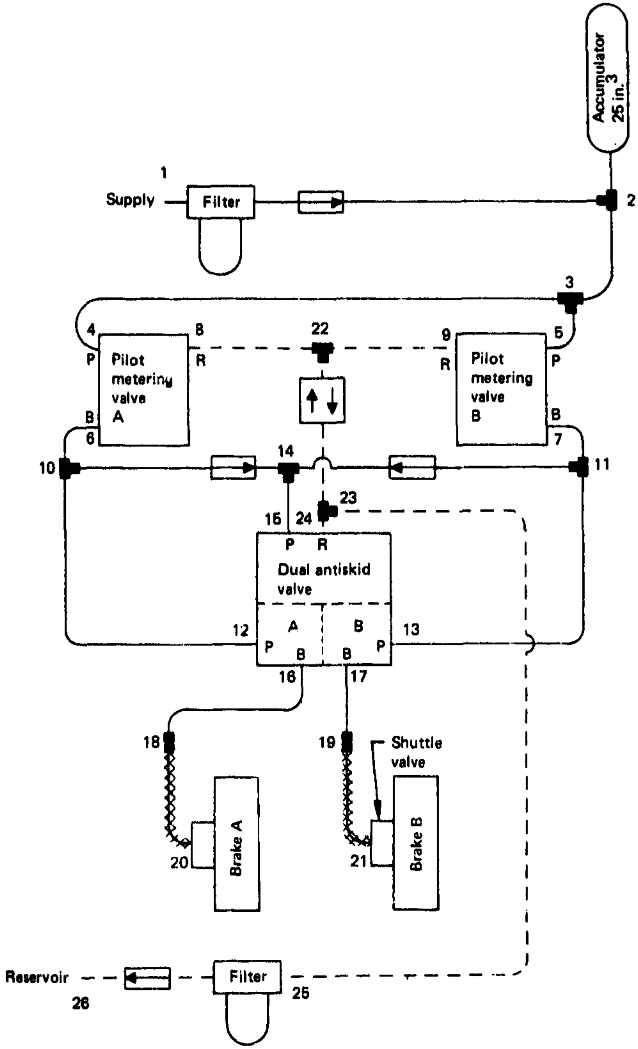

Figure 36.—F-4 Brake Hydraulic System Schematic

Table 12.—F-4 Brake Hydraulic System Mockup

Description	Index point (from-to)	Line size	Line length (in.)
Common supply line	1-2 2-3	8A– 8A–	36 48
A-system supply line	3-4	8A–	12
A-system metered pressure line	6-12 10-14	4A35 4A35	36 22
A-system brake line	16-18 18-20	4A35 1/4" hose	560 36
B-system supply line	3-5	8A–	12
B-system metered pressure line	7-13 11-14	4A35 4A35	36 22
B-system brake line	17-19 19-21	4A35 1/4" hose	304 36
Common metered pressure line	14-15	4A35	14
Return line	8-22 9-22 22-23 23-24 23-25 25-26	6A35 6A35 6A35 6A35 6A35 6A35	12 12 22 33 48 114

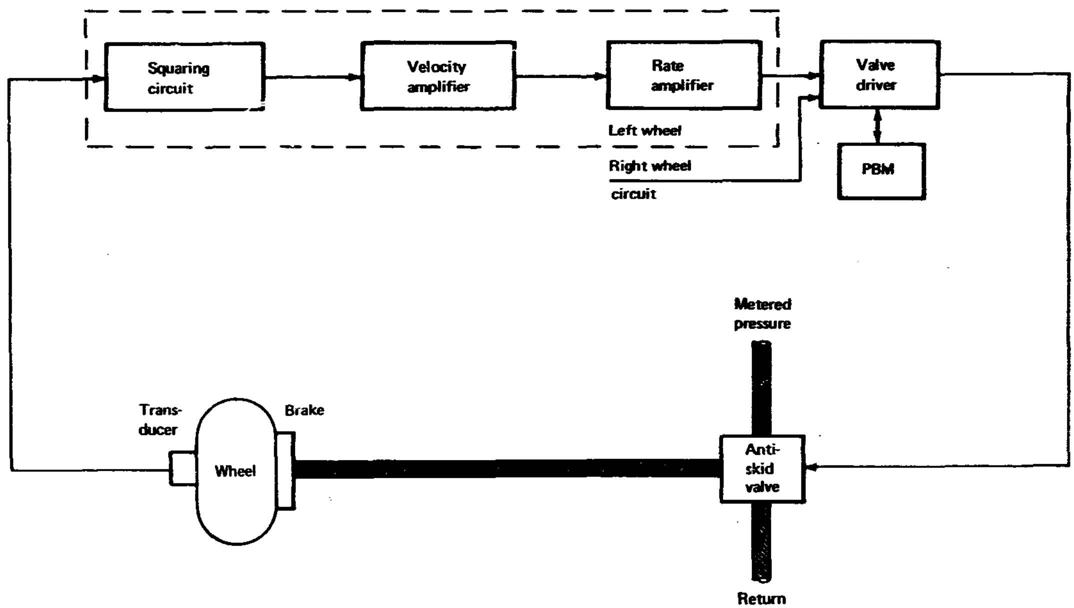

Figure 37.—F-4 Antiskid System Block Diagram

The remaining component of the system is the valve driver, which provides current to the electrohydraulic antiskid servo valve for a given voltage input from the rate amplifier.

The Mark II system used on the F-4 provides paired skid control to the two main gear wheels. Paired skid control supplies a brake release signal to both wheels even though only one wheel may be skidding.

c. LOCKED-WHEEL PROTECTION

The locked-wheel protection consists of a second rate threshold. When the deceleration rate of the wheel exceeds 120 rad/sec^2, a full dump signal is applied to the valve. Duration of the dump is a function of the recovery time of the detection circuitry.

d. BRAKE HYDRAULIC SYSTEM

The F-4 brake hydraulic system is composed of two pilot metering valves, one dual antiskid valve, and the associated tubing. The system requires a 3000-psi pressure supply to the pilot metering valves. The metering valves are pressure control devices capable of metering a desired pressure level. The two valves, right and left, supply pressure to the second stages of the right and left antiskid valves. The metered pressure level determines the maximum pressure available at the brakes. With an independent supply pressure to each antiskid valve, the pilot is capable of applying differential braking for directional control.

The antiskid valves are electrohydraulic pressure control devices. The two valves required by the F-4 have been integrated into a single dual valve module, as shown in Figure 38. The antiskid module has a common first stage and two independent second stages. The first stage consists of a flapper and nozzle while the second stages incorporate a spool and sleeve arrangement. The design of this valve is unusual; in addition to the two independent second-stage supplies from the meter valve, a third supply pressure is required for the first stage. The higher of the two pilot metered pressure levels acts as the supply to the first stage. This is accomplished through logic provided by two check valves on the inlet side of the first stage. In addition to the supply pressures, the antiskid valve is supplied with an electrical signal from the skid control box. The signal is applied to a permanent magnet torque motor that causes the flapper in the first stage to move from the neutral position. Movement unbalances the hydraulic bridge formed by the first stage nozzles; the resulting differential pressure is applied to the second stage spool. Movement of the spool allows the output of the antiskid valve to change. The hydraulic forces on the spool work to position the spool until equilibrium position and pressure are reached. The output of the antiskid valve is then transmitted to the brake.

e. BRAKES

The F-4 brakes used on the mockup were an eight-rotor brake. The modulation of pressure from the antiskid valve causes the brake stack to compress or release, resulting in a controlled braking action.

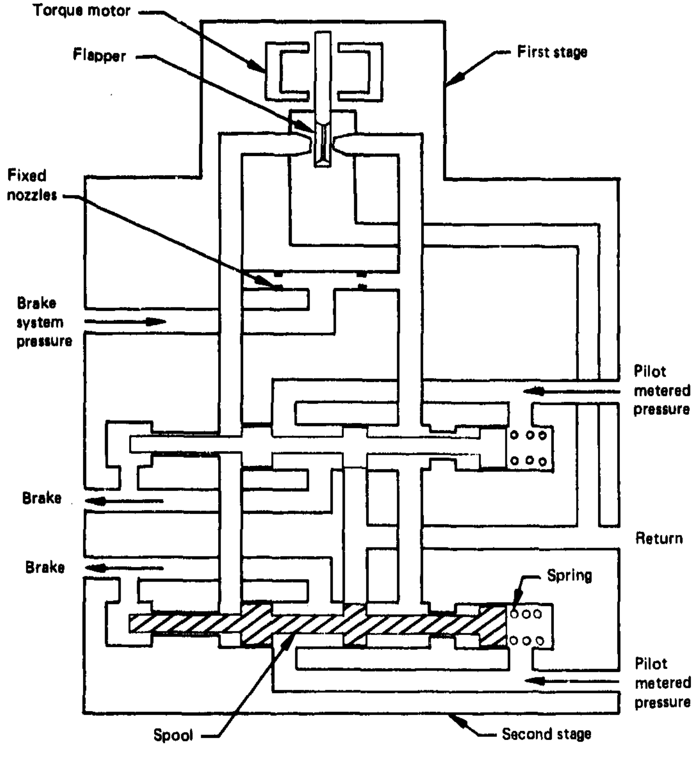

Figure 38.—F-4 Antiskid Valve Schematic (Dual Valve) (Shown Deenergized; Full Pilot Metered Pressure)

2. BRAKING SYSTEM CHARACTERISTICS

During the analysis of the hydraulic system, various system and component characteristics were measured. The dynamic response of the standard F-4 brake hydraulic system is shown in Figures 39 and 40. Figure 39 plots the system frequency response, while Figure 40 represents step response. The dynamic response data resulting from changes to the hydraulic system is compiled in Tables 13 and 14.

The pressure-current characteristics of the antiskid valve are plotted in Figure 41. The effect of varying the metered pressure is depicted by the three different curves.

Figure 42 plots the pressure-volume relationship of the standard F-4 brake. Also included are the p-v relationships for the increased brake volume and increased brake gain tests.

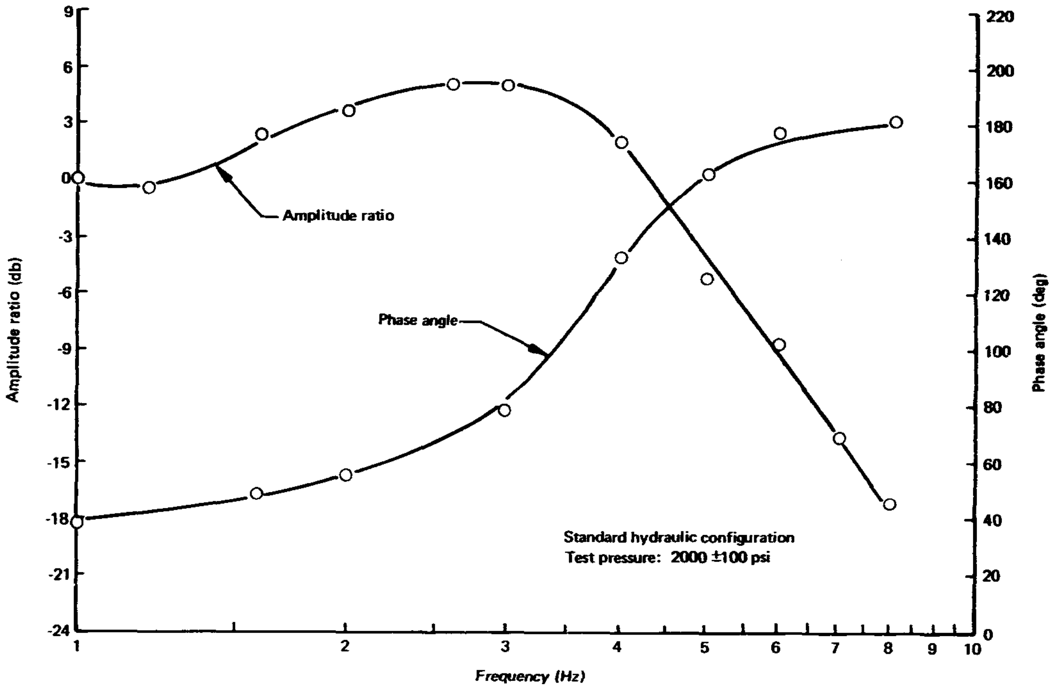

Figure 39.—F-4 Brake Hydraulic System Frequency Response

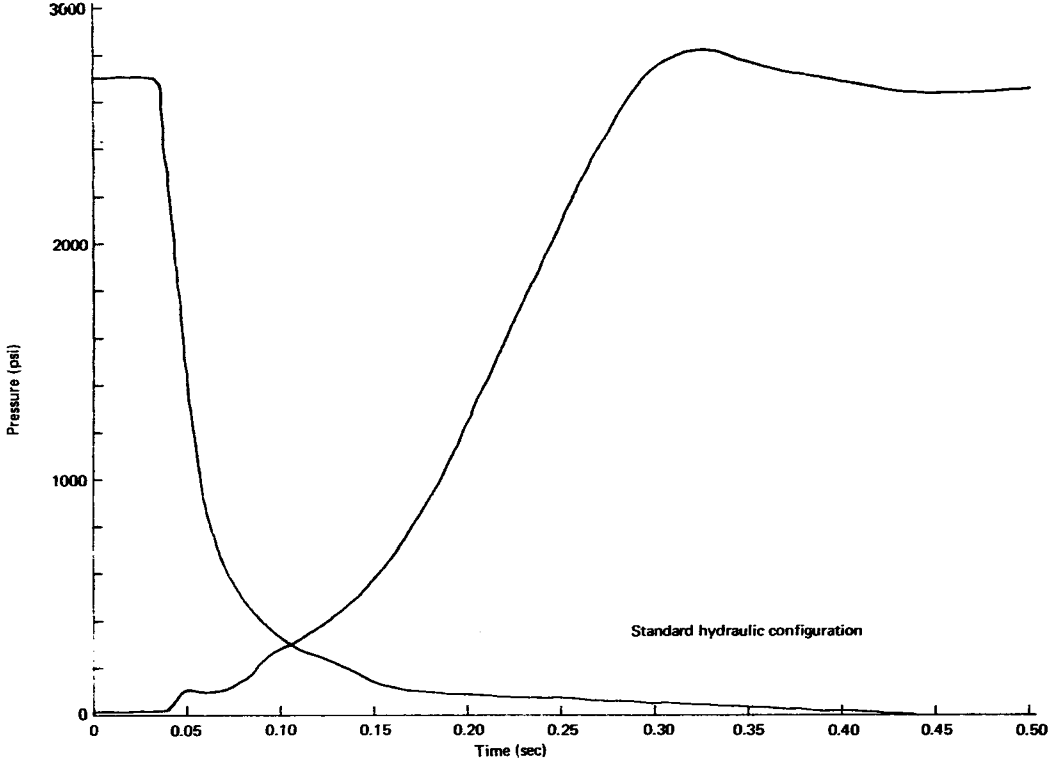

Figure 40.—F-4 Brake Hydraulic System Step Response

Table 13.—F-4 Frequency Response Data

Test condition	Test pressure (psi)(±psi)	Resonance point frequency or -3 db frequency (Hz)	Gain at resonance or -3 db (db)	Phase angle at resonance or -3 db (deg)	Frequency at 90° phase angle (Hz)
Standard	2000 100	2.8	5.0	73	3.3
	200	4	3.9	81	4.2
	1000 100	3	4.5	79	3.3
	200	3	2.1	60	4.1
a. Decrease line diameter *					
b. Increase line diameter	2000 100	1.6	.2	29	3.1
	200	2.8	.4	38	4.3
	1000 100	2.6	1.8	86	2.7
	200	3.2	1.8	65	3.7
c. Move dynamic breakpoint out 150% of nominal	2000 100	5.4	7.9	81	5.6
	200	6.0	5.2	64	7.1
	1000 100	4.4	6.2	74	5.0
	200	6.0	3.8	86	6.2
d. Move dynamic breakpoint in 50% of nominal	2000 100	2.2	2.4	77	2.5
	200	2.6	1.4	71	3.2
	1000 100	2.4	1.6	76	2.6
	200	2.6	1.0	69	3.3
e. Restriction	2000 100	2.8	3.7	78	3.1
	200	3.8	3.6	73	4.2
	1000 100	3.2	5.1	85	3.3
	200	4.0	2.5	88	4.1

* Test not run

Table 14.—F-4 Step Response Data

Test condition	Pressure step change	Delay response time (sec)		Response time to 80% of pressure change (sec)		Percentage pressure overshoot of step change	
		Pressure increase	Pressure decrease	Pressure increase	Pressure decrease	Pressure increase	Pressure decrease
Standard	0-2700	0.040	0.035	0.252	0.077	4.4	0
	0-2400	.040	.022	.245	.067	5.0	0
	0-1350	.060	.020	.270	.010	8.9	0
	600-2700	.020	.040	.110	.075	5.7	8.6
	600-2400	.020	.023	.105	.056	8.4	10.0
a. Decrease line diameter*							
b. Increase line diameter	0-2700	.03	.022	.360	.065	2.2	0
	0-2400	.03	.021	.340	.057	2.5	0
	0-1350	.045	.022	.290	.065	4.4	0
	600-2700	.017	.037	.210	.070	2.8	15.7
	600-2400	.017	.022	.185	.052	3.4	17.3
c. Move dynamic breakpoint out 150% of nominal	0-2700	.025	.022	.210	.045	4.4	0
	0-2400	.023	.010	.192	.033	3.4	0
	0-1350	.047	.012	.220	.045	6.7	0
	600-2700	.010	.030	.080	.047	4.3	12.9
	600-2400	.010	.010	.070	.027	10.0	13.4
d. Move dynamic breakpoint in 50% of nominal	0-2700	.050	.045	.300	.100	4.4	0
	0-2400	.045	.030	.286	.092	3.8	0
	0-1350	.057	.032	.300	.135	4.4	0
	600-2700	.030	.050	.145	.095	5.7	7.1
	600-2400	.030	.032	.135	.080	6.7	8.4
e. Insert 20% return line restriction	0-2700	.040	.035	.260	.080	3.4	0
	0-2400	.022	.020	.240	.070	3.8	0
	0-1350	.062	.020	.280	.115	6.7	0
	600-2700	.020	.040	.117	.075	5.7	8.5
	600-2400	.020	.022	.107	.057	6.7	10.0

*Test not run

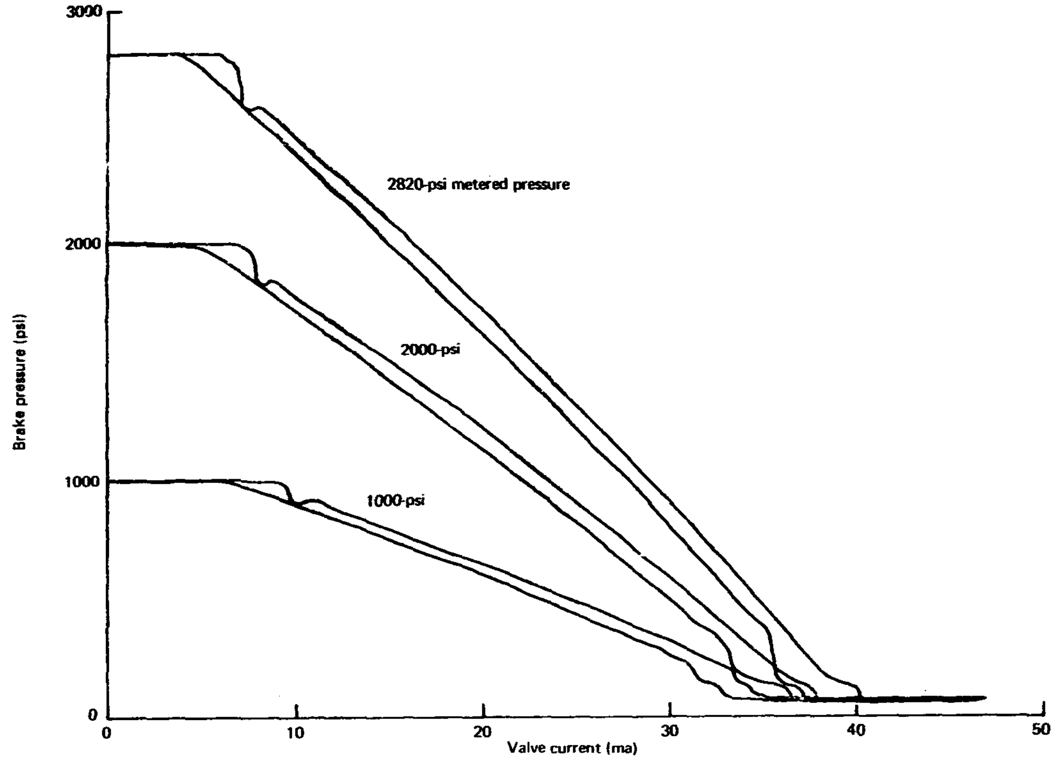

Figure 41.—F-4 Antiskid Valve Pressure-Current Characteristics

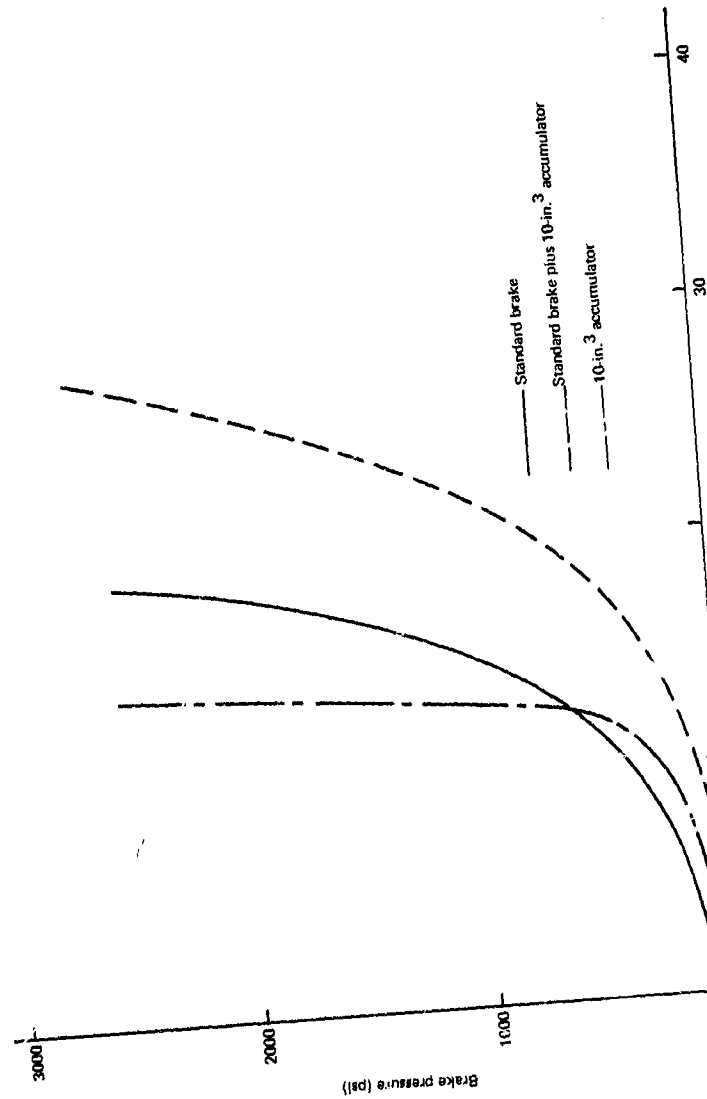

Figure 42.—F-4 Brake Pressure-Volume Characteristics

SECTION VIII

REGION OF ANTISKID SYSTEM OPERATION ON MU-SLIP CURVE

The purpose of an antiskid system is to maximize the braking effort and at the same time prevent tire skidding. The actual level of braking attained is a direct result of the antiskid system design and implementation. During the sensitivity studies, an effort was made to measure how effective each antiskid system was at maximizing braking. To determine the level of operation, an oscilloscope was used to plot ground friction (mu) verses wheel slip. The ideal antiskid system should operate at the peak of the mu-slip curve, maximizing friction and limiting slip. Actual systems operate over a region of slip and at friction levels lower than maximum. Early antiskid systems tend to operate over a wide range of slip, which results in a very low friction level. Present systems are designed to operate over a smaller slip region near the peak friction value.

The actual region of mu-slip operation is described for each antiskid system in the following paragraphs. Regions I, II, III, and IV as depicted in Figure 43, will be used to define the operational characteristics of each system.

1. Boeing 727 Mark II

The Boeing 727 Mark II antiskid system operates in regions II and III at all values of peak mu. During high-speed operation, the system cycles in region II only. However, as the aircraft slows, deep skids occur, extending system operation into region III. As brake releases occur, the system recovers from the high slip condition by cycling up the back side of the curve into region II.

2. Boeing 737 Mark III

The Boeing 737 Mark III system operates around the peak of the mu-slip curve at all peak available mu levels. At high peak mu levels, the system operates in region II. At lower peak mu values (0.1 and below), the system allows the wheel to go into deeper skids, operating in regions II and III.

3. Boeing 747 Mark III

The 747 Antiskid System limits slip to about 20-30% for peak mu values as low as 0.2. Thus, it operates predominately in region II. As available friction drops below 0.2, the wheel goes into deeper skids, reaching about 60% slip (region III) and then cycling back into region II and the brakes release.

4. C-141

The Bendix C-141 antiskid system operates over the entire range of slip, regions I, II, III, and IV, at all values of available ground friction. The system simply cycles between the free-rolling to the locked-wheel condition during the entire stop. Thus the system operates below the peak friction value most of the time.

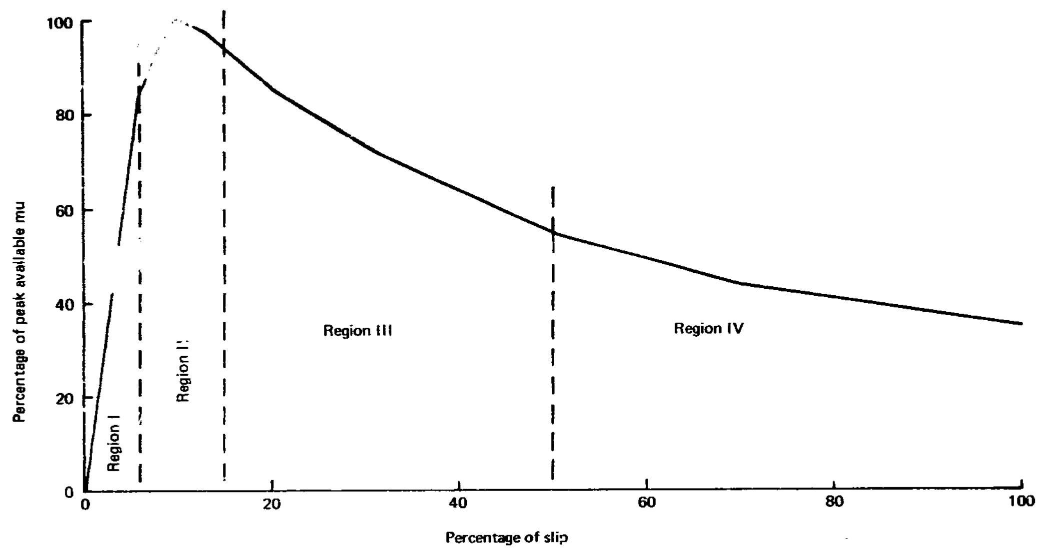

Figure 43.—Definition of Operating Regions on Mu-Slip Curve

5. F-4 Mark II

The F-4 Mark II system was found to operate in region I of the mu-slip curve when the peak available mu was greater than 0.2. At lower peak mu values, the system cycled over the peak into regions II and III. The wheel progressed into deeper and deeper skids (region IV) as the aircraft slowed.

SECTION IX

DETAILED SENSITIVITY STUDY TEST PROCEDURE AND SEQUENCE

1. TEST PROCEDURE

The sensitivity study of the braking segment consisted of nine separate system tests. The tests were implemented as the system par[illegible] were varied, one at a time, to determine the sensitivity of aircraft performance to [illegible] tests can be divided into three categories:

- Stability studies
- Performance studies
- Hydraulic system studies

The tests performed in each of these categories are outlined below.

a. STRUT STABILITY STUDIES (Test 1)

System stability is directly related to stopping performance in that severe instability will result in loss of braking and can present a serious safety hazard. In this study, the ability of a brake control system to contribute to the stability of the landing gear was evaluated. The stability margin of the system was determined by finding the damping required for stability.

The purpose of the test was to determine the contribution of the brake control system to landing gear oscillations. During a run, the brake torque was caused to peak from its nominal value to its maximum value numerous times during a stop. The timing was varied so that the steps would occur during all operational modes of the control system. The strut displacement was monitored to determine the influence of the control system on strut stability. Two gear frequencies were evaluated to cover the expected range of natural frequencies for the system. Gear damping was varied to find the point where the system becomes unstable.

Gear compliance and its effect on the wheel perturbations was also tested. The ability of the system to dampen gear oscillations for two different compliances was assessed.

b. PERFORMANCE STUDIES

The brake system was evaluated under four different conditions chosen to provide a measure of its performance capability. These include airplane touchdown dynamics, stabilized landing, step mu change, and wet runway. Of the four tests, three fall into the general category of system adaptability to typical operating conditions. Icy or wet patches on an otherwise dry runway were simulated by the step mu test. Typical load changes encountered during high sink rate landings were simulated. Mu changes with speed as encountered on a wet runway were evaluated. The other condition covers the general category of stabilized performance.

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1. **Touchdown Dynamics** (Test 2)

The purpose was to determine transient response upon touchdown. During testing, the air vehicles were braked at a preselected brake application speed V_A. During the braking run from speed V_A to V_B, mu was varied in a manner to simulate a typical touchdown load profile of the airplane being tested. The available ground mu was restored to its full initial maximum value when braked-vehicle speed reached a value of V_B. Full pilot metered pressure was available during this and other runs, unless specifically mentioned otherwise.

2. **Stabilized Landing** (Test 3)

The purpose of these tests was to measure brake system efficiency under a stabilized braked condition and to determine the skid index and cornering index. The tests determined a baseline performance for each system.

During the tests, the vehicle was braked at a preselected braked speed V_{BA}. Braking was continued until the vehicle was brought to a full stop. During these tests, the available maximum ground mu was held at a constant value throughout the entire run. This value was varied from one run to another to cover the entire range of available ground mu (0.05, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6). A random noise generator was used to input a disturbance on mu to simulate a typical runway roughness profile for selected conditions.

3. **Mu Steps** (Test 4)

The purpose of this test was to measure brake system adaptability during adverse runway conditions, such as tar strips or icy patches on the runway.

The test was designed to simulate sudden changes of available ground mu resulting from water puddles, icy patches, or the presence of tar strips.

The braking run proceeded for the first few seconds with a high available mu. Then the first of several mu step changes occurred. Each consisted of a pulse width of 750 milliseconds dropping the mu to 0.1. After each pulse, the mu was restored to its high value for 5 seconds. Thus during the test, the system was subjected to several step changes so that its operation under a variety of conditions could be observed. A poorer performing system encountered more step changes than a better system.

4. **Wet Runway** (Test 5)

The purpose of this test was to study system performance under adverse runway conditions. During the test, the value of peak available ground mu was made to vary from a low value at high speed to a high value at low speed (Figure 44). This relationship is representative of the available ground mu normally encountered on a wet runway. The value of mu at high speed was modified in some cases to allow the wheel ample ground friction to spin up the wheel.

Figure 44.--Mu-Speed Curve for Wet Runway

5. Hydraulic System Response (Tests 6 and 7)

Frequency response and step response tests were run on the brake hydraulic system. Frequency response tests were run over the frequency range of 0.5 to 50 Hz and at amplitudes of ±100 psi and ±200 psi. This test was conducted at mean pressure levels of 33% and 66% of supply pressure.

The step response curves consisted of the following steps indicated in percentage of supply pressure:

From	To
0	50
0	90
100	20
100	0
90	20

The input to both tests was valve current, and the output was the pressure at the brake.

6. Antiskid Valve Characteristics (Test 8)

Static pressure versus current curves were also run on the servo valve for each airplane at metered pressure levels of 33%, 66%, and 100% of supply.

7. Hydraulic System Pressure–Volume Characteristics (Test 9)

Pressure-volume characteristics were measured for each brake The test conditions are listed in ASD-TR-74-41, Volume I, Section V.

2. TEST SEQUENCE

The sequence of the tests is given in Table 15.

Table 15.—Test Sequence

Condition	Test	Variable changed
Airplane		
Baseline	1-9	...
1a	3, 5	W, I_{yy}, v_B
1b	3, 5	W, I_{yy}, v_B
2a	3, 5	H_B,
2b	3, 5	H_B,
2c	3, 5	I_{yy}, I_A, L_B
2d	3, 5	I_{yy}, L_A, L_B
3a	3, 5	v_{app}
3b	3, 5	v_{app}
4a	2, 3, 5	Spoiler time
4b	2, 3, 5	Spoiler time
4c	3, 5	C_L, C_D
4d	3, 5	C_L, C_D
4e	3, 5	F_{eo}, Ke
4f	3, 5	F_{eo}, Ke
5a	1, 2, 3, 5	Pressure application rate
5b	1, 2, 3, 5	Pressure application rate
5c	1, 2, 3, 5	Pressure application time
5d	1, 2, 3, 5	Pressure application time
Runway and Environmental System		
Baseline	3, 5	...
1a	3, 5	v_{wind}
1b	3, 5	v_{wind}
1c	3, 5	v_{wind}
2a, b	3, 5	σ_D
3a	3, 5	Runway roughness
3b	4	Runway discontinuities

Table 15.—Test Sequence (Continued)

Condition	Test	Variable changed
Landing Gear System		
Baseline	3, 5	---
1a	3 (0.4 mu and greater)	M_B
1b	3 (0.4 mu and greater)	M_B
1c	1, 3, 5	T_{BP}
1d	1, 3, 5	T_{BP}
1e	1, 3	Break frequency
1f	1, 3	Break frequency
1g	1, 3, 5	T_{BG}
1h	1, 3, 5	T_{BG}
1i	1, 3, 5	T_{BG}
1j	1, 3, 5	T_{BG}
2a	1, 3	$\mu \cdot \sigma$ Slope
2b	1, 3	$\mu \cdot \sigma$ Slope
2c	3, 5	R, Iw, Mw, wet runway mu
2d	3, 5	R, Iw, Mw, A, wet runway mu
2e	3, 5	$\mu \cdot \sigma$ shape
2f	3, 5	$\mu \cdot \sigma$ shape
3a	1, 3	M_s
3b	1 3	M_s
3c	1, 3	K_s
3d	1, 3	K_s
3e	3, 5	K_o, K_{on}
3f	3, 4, 5	K_o, K_{on}
3g	3, 4, 5	C_o, C_{on}
3h	3, 4, 5	C_o, C_{on}

Table 15.—Test Sequence (Concluded)

Condition	Test	Variable changed
Hydraulics		
Baseline	3, 5	---
1a	1, 3, 6, 7	Line diameter
1b	1, 3, 6, 7	Line diameter
1c	1, 3, 6, 7	Line length
1d	1, 3, 6, 7	Line length
1e	1, 3, 4, 7	Return line restriction
1f	1, 3, 9	Brake volume
1g	1, 3, 9	Brake volume

SECTION X

PERFORMANCE INDICES

Tables 16 through 25 contain the numerical values of the performance indices for all of the aircraft tested. Listed for each test condition is the available friction (mu), airplane braking distance (X_A), perfect braking distance (X_P), braking distance efficiency (η_S), developed mu efficiency (η_D), skid index (SI), and cornering index (CI).

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Table 16.—727 Baseline Braking Data

Condition	Mu	X_A	X_p	η_s	η_D	SI	CI
Test 2:							
Touchdown dynamics	0.6	1418	1087	76.66	71.50	24.82	53.76
	0.5	1574	1259	79.99	74.01	24.54	49.96
	0.4	1854	1505	81.18	73.37	18.80	46.46
	0.3	2494	1893	75.90	64.60	19.33	35.48
	0.2	4872	2595	53.26	38.82	15.45	28.85
	0.1	9107	4321	47.45	33.89	7.26	25.78
Test 3:							
Stable landing	0.6	1278	1087	85.05	15.21	29.05	53.72
	0.5	1456	1259	86.46	75.63	24.20	51.42
	0.4	1750	1505	86.00	74.24	18.97	49.12
	0.3	2250	1893	84.13	69.76	15.65	41.81
	0.2	4192	2395	61.30	47.19	15.99	28.31
	0.1	3762	4321	49.32	34.16	7.37	27.07
Test 4:							
Mu steps	0.1 to 0.5	1734	---	---	64.27	18.83	51.81
Test 5:							
Wet runway	0.05 to 0.05	5010	3328	66.43	44.91	15.35	17.33

Table 17.—727 Sensitivity Test Data

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_D	SI	CI
1a	Maximum Landing Weight							
	Stabilized Landing	.6	[illegible]	1232	89.02	[illegible]	[illegible]	[illegible]
		.4	[illegible]	1701	88.55	[illegible]	[illegible]	38.96
		.2	[illegible]	2914	63.64	46.48	[illegible]	[illegible]
	Wet Runway		[illegible]	3944	67.38	[illegible]	11.38	14.99
1b	Minimum Landing Weight							
	Stabilized Landing	.6	[illegible]	869	82.68	[illegible]	[illegible]	50.90
		.4	[illegible]	1207	79.15	[illegible]	[illegible]	41.93
		.2	[illegible]	2098	49.65	[illegible]	[illegible]	30.81
	Wet Runway		[illegible]	2509	65.05	44.18	[illegible]	16.98
2a	High Center of Gravity							
	Stabilized Landing	.6	TEST	NOT	RUN			
		.4						
		.2						
	Wet Runway							
2b	Low Center of Gravity							
	Stabilized Landing	.6	TEST	NOT	RUN			
		.4						
		.2						
	Wet Runway							
2c	Forward Center of Gravity							
	Stabilized Landing	.6	[illegible]	1127	86.43	76.64	28.75	52.46
		.4	1796	1558	86.75	[illegible]	19.53	45.63
		.2	4520	2677	55.56	37.29	15.58	28.17
	Wet Runway		5112	5302	64.59	44.52	14.79	16.48
2d	Aft Center of Gravity							
	Stabilized Landing	.6	1244	1061	85.29	76.67	30.33	53.95
		.4	1586	1470	87.19	76.05	20.67	[illegible]
		[illegible]	4118	2535	60.89	[illegible]	16.10	30.50
	Wet Runway		[illegible]	3260	66.84	[illegible]	15.76	17.13
3a	Brakes on Speed + 10%							
	Stabilized Landing	.6	[illegible]	1288	87.44	[illegible]	33.47	[illegible]
		.4	2004	1767	88.22	[illegible]	21.98	[illegible]
		.2	[illegible]	2983	59.51	40.16	11.75	27.48
	Wet Runway		[illegible]	3612	66.14	45.18	[illegible]	[illegible]
3b	Brakes on Speed + 20%							
	Stabilized Landing	.6	[illegible]	1510	[illegible]	[illegible]	[illegible]	[illegible]
		.4	[illegible]	2052	[illegible]	[illegible]	23.44	[illegible]
		.2	[illegible]	3392	61.26	[illegible]	[illegible]	[illegible]
	Wet Runway		[illegible]	4215	70.41	[illegible]	[illegible]	[illegible]
4a	Drag Device Deployment 1.0 Second After Touchdown							
	Stabilized Landing	.6	[illegible]	1156	86.26	[illegible]	[illegible]	53.20
		.4	[illegible]	1513	87.15	80.49	[illegible]	[illegible]
		.2	[illegible]	2662	[illegible]	[illegible]	14.66	[illegible]
	Wet Runway		[illegible]	3417	[illegible]	[illegible]	14.13	14.95
	Touchdown Profile	.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41.43
		.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		.2	[illegible]	[illegible]	[illegible]	[illegible]	14.76	[illegible]

Table 17.—727 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_a	η_D	SI	$\bar{CI}$
4b	Drag Device Deployment 2.0 second after touchdown							
	Stabilized Landing	.6	1400	1213	86.69	80.07	15.14	49.68
		.4	1800	1637	90.94	79.16	14.06	45.93
		.2	4673	2730	59.05	43.78	14.98	26.85
	Wet Runway		5140	3548	69.03	49.35	14.30	13.92
	Touchdown Profile	.6	1620	1213	74.87	75.62	17.27	46.05
		.4	2062	1637	79.39	77.67	14.68	39.75
		.2	4[illegible]66	2730	57.28	41.74	14.44	26.46
4c	No Spoilers/Drag Devices							
	Stabilized Landing	.6	1535	1386	90.29	75.75	22.14	39.31
		.4	2200	1975	87.50	64.59	21.59	23.64
		.2	5612	3348	59.66	39.36	12.68	21.30
	Wet Runway		Wheel	Locks Up,	Would	Not	Run	
4d	60% Effective Spoilers							
	Stabilized Landing	.6	1374	1185	86.24	88.92	15.87	81.00
		.4	1903	1642	86.28	92.87	14.25	42.92
		.2	5022	2840	56.55	41.80	14.48	25.66
	Wet Runway		Wheel	Locks Up,	Would	Not	Run	
4e	40% Effective Spoilers							
	Stabilized Landing	.6	1438	1243	86.44	86.34	15.63	49.32
		.4	1986	1724	86.81	79.37	18.15	55.50
		.2	5352	2987	55.81	41.20	14.05	24.70
	Wet Runway		Wheel	Locks Up,	Would	Not	Run	
4f	120% Engine Idle Thrust							
	Stabilized Landing	.6	1303	1098	84.27	83.39	26.62	53.56
		.4	1776	1526	85.92	84.10	18.28	47.08
		.2	4732	2657	56.15	43.65	15.28	29.30
	Wet Runway		5191	3457	66.60	49.45	15.13	16.45
4g	80% Engine Idle Thrust							
	Stabilized Landing	.6	1273	1077	84.60	83.20	26.94	52.94
		.4	1129	1485	85.89	83.80	18.19	47.01
		.2	4055	2535	59.37	44.62	16.10	27.59
	Wet Runway		4747	3243	68.32	49.05	15.14	16.18
5a	150% Nominal Pressure Application Rate							
	Stabilized Landing	.6	1260	1087	86.27	83.40	26.51	53.40
		.4	1716	1505	87.70	88.77	18.22	46.80
		.2	4350	2594	59.63	43.28	16.04	27.87
	Wet Runway		4737	3328	70.25	49.71	14.92	16.86
	Touchdown Profile	.6	1424	1087	76.33	79.68	24.50	51.41
		.4	1856	1505	81.09	80.19	19.80	42.70
		.2	4515	2594	57.45	44.16	16.03	26.58

Table 17.—727 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_B	SI	CI
5b	50% Nominal Pressure Application Rate							
	Stabilized Landing		[illegible]	1087	82.74	[illegible]	26.89	[illegible]
		.4	1745	1505	86.75	[illegible]	18.[illegible]	[illegible]
		.2	4234	2594	61.27	44.82	[illegible]	[illegible]
	Wet Runway		[illegible]	3328	70.39	[illegible]	14.96	[illegible]
	Touchdown Profile	.6	1413	1087	76.93	77.35	22.48	55.47
		.4	1817	1505	87.82	82.00	17.71	46.03
		.2	4500	2594	57.64	42.73	16.13	26.51
5c	Nominal Rate at 2.0 seconds From Touchdown							
	Stabilized Landing	.6	1180	1007	84.74	68.80	12.48	61.10
		.4	1620	1393	85.46	71.46	11.38	53.90
		.2	4069	2437	59.89	42.67	13.13	32.03
	Wet Runway		4620	2972	64.33	47.96	13.94	19.24
	Touchdown Profile	.6	1220	1000	81.97	69.95	13.05	60.00
		.4	1672	1395	83.31	72.53	12.17	51.25
		.2	4271	2437	57.06	41.41	13.19	30.41
5d	Nominal Rate at 4.0 Seconds From Touchdown							
	Stabilized Landing	.6	1112	932	83.81	56.68	9.70	67.71
		.4	1525	1303	85.44	62.91	9.59	59.27
		.2	3874	2296	59.26	40.52	17.15	35.40
	Wet Runway		4293	2610	60.79	46.24	13.12	24.33
	Touchdown Profile	.6	1131	932	82.40	58.11	11.10	65.49
		.4	1560	1303	83.53	[illegible]35	10.64	56.18
		.2	4040	2296	56.80	[illegible]66	12.03	33.71
5e	75% Of Full Metered Pressure							
	Stabilized Landing	.6	1360	1087	79.93	79.57	21.67	61.21
		.4	1856	1505	81.09	74.84	14.17	57.57
		.2	4426	2594	58.61	40.66	5.50	70.95
	Wet Runway		5212	3328	63.85	44.27	2.66	70.65
5f	50% Of Full Metered Pressure							
	Stabilized Landing	.6	1598	1087	68.02	65.23	15.57	68.28
		.4	1818	1505	82.78	79.67	14.73	85.90
		.2	5003	2594	51.85	35.94	2.39	76.89
	Wet Runway		5369	3328	61.99	40.45	1.97	75.80
1a	10 Knot Wind							
	Stabilized Landing	.6	1066	907	85.08	[illegible]	23.41	54.00
		.4	1434	1252	87.31	81.38	[illegible]	41.[illegible]
		.2	[illegible]	2137	63.37	44.[illegible]	[illegible]	30.49
	Wet Runway		[illegible]	2527	71.12	[illegible]	14.46	[illegible].44
1b	20 Knot Wind							
	Stabilized Landing	.6	[illegible]	708	81.00	82.18	[illegible]	[illegible]
		.4	[illegible]	971	82.29	[illegible]	[illegible]	[illegible]
		.2	2688	1623	60.38	43.31	[illegible]	[illegible]
	Wet Runway		[illegible]	1871	71.33	[illegible]	[illegible]	[illegible]

Table 17.—727 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_a	η_D	SI	CI
1e	-10 Knot Wind							
	Stabilized Landing	.6	1508	1305	86.54	83.17	29.73	53.58
		.4	2042	1814	88.83	83.85	20.08	47.70
		.2	5164	3165	61.29	45.67	18.15	26.64
	Wet Runway		5945	4296	72.26	48.60	16.65	14.83
2a	Hot Day - High Altitude							
	Stabilized Landing	.6	1303	1108	85.03	83.20	27.48	53.04
		.4	1788	1550	86.69	82.27	18.72	47.07
		.2	4510	2733	59.80	45.73	16.78	27.20
	Wet Runway		5444	3709	68.13	48.28	15.73	14.91
2b	Cold Day - Sea Level							
	Stabilized Landing	.6	1236	1058	85.60	83.12	25.97	53.45
		.4	1654	1446	87.42	81.38	17.40	47.37
		.2	3825	2422	63.32	43.74	16.00	29.19
	Wet Runway		4021	2966	73.76	44.76	14.54	17.93
3a	Rough Surface Runway							
	Stabilized Landing	.6	[illegible]	1087	84.99	84.17	28.93	50.72
		.4	1753	1505	85.85	84.35	18.22	43.04
		.2	4190	2594	61.91	44.80	16.26	27.42
	Wet Runway		4811	[illegible]	[illegible]	51.22	15.36	15.74
1a	High Fade Brake							
	Stabilized Landing	.6	1261	1087	86.20	85.41	28.18	51.15
		.5	1450	1259	86.83	82.96	21.99	51.61
		.4	1726	1505	87.20	82.60	18.[illegible]	47.62
1b	Low Fade Brake							
	Stabilized Landing	.6	1280	1087	84.92	85.18	26.52	53.54
		.5	1448	1259	86.95	83.24	22.35	51.06
		.4	1729	1505	87.04	82.11	18[illegible]	47.62
1c	Torque Peaking to 150% of Running							
	Stabilized Landing	.6	1286	1087	84.53	81.44	26.30	54.11
		.4	1733	1505	86.84	81.60	11.71	48.38
		.2	4128	2594	62.84	46.04	15.73	29.20
	Wet Runway		4720	3328	70.51	49.63	14.[illegible]	17.08
1d	No Torque Peaking							
	Stabilized Landing	.6	1274	1087	85.32	84.12	27.1[illegible]	52.74
		.4	1728	1505	87.09	82.87	18.45	46.57
		.2	4134	2594	62.75	41.05	17.12	24.83
	Wet Runway		4718	3328	70.54	49.59	15[illegible]	15.92
1e	Torque Response Break Point 150% Nominal							
	Stabilized Landing	.6	1217	1087	85.12	85.01	27.[illegible]	52.91
		.4	1720	1505	87.50	82.88	18[illegible]	46.09
		.2	4182	2594	62.03	45.40	16.35	27.28
1f	Torque Response Break Point 50% Nominal							
	Stabilized Landing	.6	1291	1087	84.20	81.77	26.[illegible]	54.63
		.4	1732	1505	86.89	81.45	17[illegible]	48.65
		.2	4124	2594	62.90	45.98	15.[illegible]	28.17

Table 17.—727 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_D	SI	CI
1g	Torque Gain 120% of Nominal							
	Stabilized Landing	.6	[illegible]	1087	83.81	84.97	21.97	52.23
		.4	1830	1505	82.24	11.69	19.85	44.47
		.2	5028	2594	51.59	38.57	15.45	31.41
	Wet Runway		5113	3328	65.09	47.15	16.68	15.91
1h	Torque Gain 80% of Nominal							
	Stabilized Landing	.6	1377	1087	78.94	77.70	19.33	62.74
		.4	1715	1505	87.86	87.37	17.37	50.22
		.2	3720	2694	69.73	69.78	16.11	27.19
	Wet Runway		4674	3328	71.22	54.68	15.19	14.88
1i	Variable Torque Gain T = F (p)[5]							
	Stabilized Landing	.6	1319	1087	82.41	86.81	25.09	57.37
		.4	1712	1505	87.91	88.75	19.34	46.34
		.2	4951	2694	52.39	41.10	15.68	31.02
	Wet Runway		5000	3328	66.56	49.78	15.85	15.20
1j	Linear Torque Gain T = F(p)							
	Stabilized Landing	.6	1304	1087	85.86	86.83	28.33	62.12
		.4	1767	1505	85.17	85.48	16.71	51.24
		.2	3090	2594	83.95	76.36	12.65	31.87
	Wet Runway		4607	3328	72.24	57.06	14.68	15.71
2a	Tire Inflation Pressure 120% of Nominal							
	Stabilized Landing	.6	1295	1087	83.94	82.47	19.22	69.92
		.4	1823	1505	82.56	79.97	17.83	62.92
		.2	5398	2894	48.05	35.27	14.06	27.74
2b	Tire Inflation Pressure 80% of Nominal							
	Stabilized Landing	.5	1509	1087	83.04	88.48	36.12	36.67
		.4	1742	1505	86.39	86.42	24.72	32.03
		.2	3720	2594	69.75	56.86	19.83	26.16
2c	50% Worn Tire							
	Stabilized Landing	.6	1292	1087	84.13	85.16	26.69	52.77
		.4	1756	1505	85.71	82.27	17.55	47.80
		.2	4247	2594	61.08	48.26	16.19	28.81
	Wet Runway		5025	3328	66.23	49.54	14.54	15.25
2d	80% Worn Tire							
	Stabilized Landing	.6	1303	1087	83.42	81.94	24.83	53.38
		.4	1820	1505	82.69	77.87	17.35	46.71
		.2	4612	2594	56.24	39.20	14.80	33.36
	Wet Runway		5139	3328	64.76	47.27	14.43	16.91
2e	Low Tire Heating							
	Stabilized Landing	.6	1266	1087	85.86	88.31	30.22	50.83
		.4	1705	1505	88.27	87.20	17.97	45.20
		.2	3149	2594	82.38	70.92	25.56	21.25
	Wet Runway		3831	3328	86.86	77.89	26.69	10.26
2f	Flat μ - σ peak							
	Stabilized Landing	.6	1234	1087	88.09	90.00	32.86	43.67
		.4	1673	1505	89.96	90.10	22.20	37.74
		.2	3037	2594	85.41	75.18	24.07	18.67
	Wet Runway		3704	3328	64.85	82.43	21.84	8.69

Table 17.—727 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_D	SI	CI
3a	Maximum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	1288	1087	84.92	85.61	27.73	53.30
		.4	1753	1505	85.85	84.75	18.79	46.80
		.2	4347	2594	59.67	46.17	16.20	27.40
3b	Minimum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	1376	1087	79.00	79.79	25.98	66.96
		.4	1756	1505	85.71	84.66	18.50	47.62
		.2	4353	2594	59.59	47.97	16.86	26.42
3c	Maximum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	1258	1087	86.41	89.59	30.31	50.08
		.4	1744	1505	86.30	82.70	18.67	48.33
		.2	3935	2594	65.92	51.41	16.90	28.20
3d	Minimum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	1391	1087	78.15	81.50	23.8[illegible]	66.13
		.4	1768	1505	85.12	83.73	18.14	48.06
		.2	4298	2594	60.35	47.98	16.84	28.86
3e	Vertical Stiffness 120% of Nominal							
	Stabilized Landing	.6	1294	1087	84.00	85.55	27.04	64.28
		.4	1755	1505	85.75	84.60	18.26	48.15
		.2	4161	2594	62.34	49.92	16.48	27.38
	Wet Runway		4886	3328	68.11	51.60	15.45	18.17
3f	Vertical Stiffness 80% of Nominal							
	Stabilized Landing	.6	1272	1087	85.46	88.49	29.20	50.94
		.4	1751	1505	86.95	84.66	18.27	47.70
		.2	4262	2594	60.86	48.80	15.92	28.45
	Wet Runway		4891	3328	68.04	51.32	16.47	15.21
3g	Vertical Damping 120% of Nominal							
	Stabilized Landing	.6	1274	1087	85.32	88.41	29.02	51.14
		.4	1745	1505	86.25	85.65	18.62	47.04
		.2	4266	2594	60.81	49.18	15.95	28.12
	Wet Runway		4884	3328	68.14	51.46	15.42	15.38
	Mu Steps		1754			67.93	10.65	50.03
3h	Vertical Damping 80% of Nominal							
	Stabilized Landing	.6	1277	1087	85.12	88.05	28.73	51.48
		.4	1748	1505	86.10	85.24	18.54	47.20
		.2	4215	2594	61.54	49.54	16.48	26.95
	Wet Runway		4877	3328	68.24	51.65	15.34	15.50
	Mu Steps		1709			72.22	10.81	52.55
1a	Decrease Line Diameter 50%							
	Stabilized Landing	.6	1275	1087	85.25	84.82	27.57	52.20
		.4	1788	1505	84.17	79.06	17.54	50.41
		.2	4266	2594	60.81	48.85	16.65	27.31
1b	Increase Line Diameter 50%							
	Stabilized Landing	.6	1300	1087	83.62	80.64	26.23	54.54
		.4	1799	1505	83.66	78.08	17.41	[illegible].51
		.2	4492	2594	51.15	45.44	15.86	34.73

Table 17.—727 Sensitivity Test Data (Concluded)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_A	η_B	SI	CI
1c	Move Dynamic Break Point Out 150% of Nominal							
	Stabilized Landing	.6	1280	1087	84.92	85.48	27.49	52.26
		.4	1714	1505	87.81	85.22	19.50	46.20
		.2	4217	2594	61.51	49.42	17.28	22.67
1d	Move Dynamic Break Point in 50% of Nominal							
	Stabilized Landing	.6	1270	1087	85.69	85.32	26.90	52.08
		.4	1771	1505	89.98	81.15	17.85	48.24
		.2	4688	2594	55.33	41.76	16.13	26.91
1e	Insert 20% Restriction in Return Line							
	Stabilized Landing	.6	1271	1087	85.52	86.61	29.26	51.22
		.4	1747	1505	86.15	82.20	18.51	48.46
		.2	4118	2594	62.99	49.10	16.65	26.65
	Mu Steps		1767			69.90	17.31	52.78
1f	Increase Brake Volume by 10 in ^{3}							
	Stabilized Landing	.6	1269	1087	85.66	83.25	26.51	52.81
		.4	1750	1505	86.00	81.10	18.23	47.93
		.2	4462	2594	58.12	44.32	16.57	25.12
1g	Increase Brake psV Gain							
	Stabilized Landing	.6	1358	1087	80.04	80.60	23.10	55.17
		.4	1708	1505	88.11	85.50	18.81	45.89
		.2	4349	2594	59.65	46.68	17.92	28.58

Table 18.—737 Baseline Braking Data

Condition	Mu	X_A	X_p	η_s	η_D	Si	CI
Test 2:							
Touchdown dynamics	0.6	1237	914	73.80	77.14	27.10	51.82
	0.5	1348	1063	78.86	80.53	25.13	48.15
	0.4	1549	1280	52.63	83.12	20.84	45.40
	0.3	1896	1626	85.76	84.53	16.00	43.10
	0.2	2561	2263	88.36	86.54	10.92	39.38
	0.1	4342	3883	89.43	57.84	4.95	37.44
	0.05	7528	6439	85.53	83.64	2.22	36.56
Test 3:							
Stabilized landing	0.6	1063	914	85.58	82.90	32.09	51.22
	0.5	1215	1063	87.49	85.20	27.22	46.84
	0.4	1440	1280	88.88	86.06	21.59	46.84
	0.3	1796	1626	90.53	87.41	16.06	44.84
	0.2	2454	2263	92.22	88.49	10.57	42.04
	0.1	4182	3883	92.85	88.53	5.28	35.63
	0.05	7079	6439	90.96	31.94	2.54	32.12
Test 4:							
Mu steps	0.1 to 0.5	1399	---	---	71.88	20.76	54.81
Test 5:							
Wet runway*	0.05 to 0.06	3207	2722	84.88	87.83	6.69	34.10

* An average of data from runs yielding X_A values of 3171 and 3244.

Table 19.—737 Sensitivity Test Data

CONDITION	DESCRIPTION	MU	X_A	X_P	η	η_D	SI	CI
1a	Maximum Landing Weight							
	Stabilized Landing	.6	[illegible]	[illegible]	[illegible]	[illegible]	48.69	[illegible]
		.4	[illegible]	[illegible]	87.29	[illegible]	31.99	47.96
		.2	3176	2394.7	92.61	87.52	15.76	47.56
	Wet Runway		[illegible]	[illegible]	84.13	90.35	8.58	44.02
1b	Minimum Landing Weight							
	Stabilized Landing	.6	965	829	86.35	[illegible]	24.17	48.69
		.4	1357	1160	89.09	86.16	16.00	45.70
		.2	2231	2044	91.67	[illegible]	1.97	40.36
	Wet Runway		2770	2326	85.97	85.00	7.06	30.39
2a	High Center of Gravity							
	Stabilized Landing	.6	1084	920	84.87	81.44	31.00	52.80
		.4	1448	1287	88.8[illegible]	86.22	21.73	46.76
		.2	2469	2269	91.90	88.45	10.78	41.56
	Wet Runway		3249	2715	83.56	84.18	9.12	29.52
2b	Low Center of Gravity							
	Stabilized Landing	.6	1064	911	85.62	85.43	32.84	50.62
		.4	1444	1277	88.43	86.22	21.95	46.78
		.2	2468	2261	91.61	88.66	10.68	41.86
	Wet Runway		3196	2707	84.73	90.62	7.90	38.02
2c	Forward Center of Gravity							
	Stabilized Landing	.6	1116	957	8575	83.41	30.70	50.96
		.4	1502	1389	89.15	86.52	20.84	46.26
		.2	2570	2361	91.87	88.67	10.15	41.56
	Wet Runway		3340	2802	83.89	85.08	8.60	29.78
2d	Aft Center of Gravity							
	Stabilized Landing	.6	1050	[illegible]	84.76	82.74	34.46	51.30
		.4	[illegible]	1224	88.18	86.15	23.15	47.19
		.2	2372	2172	91.57	88.54	11.35	42.07
	Wet Runway		3182	2615	82.18	81.98	10.19	27.52
3a	Brakes on Speed + 10%							
	Stabilized Landing	.6	1266	1096	[illegible]	81.52	34.55	51.87
		.4	1697	1522	89.69	85.47	[illegible]	47.26
		.2	2850	2638	92.56	86.88	11.32	43.04
	Wet Runway		3883	3448	[illegible]	89.42	[illegible]	[illegible]
3b	Brakes on Speed + 20%							
	Stabilized Landing	.6	[illegible]	[illegible]	87.99	84.44	38.87	49.15
		.4	[illegible]	[illegible]	90.85	[illegible]	[illegible]	46.06
		.2	[illegible]	[illegible]	93.35	86.52	[illegible]	[illegible]
	Wet Runway		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4a	Drag Device Deployment 1.0 Second After Touchdown							
	Stabilized Landing	.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Wet Runway		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Touchdown Profile	.6	[illegible]			[illegible]	[illegible]	[illegible]
		.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 19.—737 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_D	SI	$\bar{C}I$
4b	Drag Device Deployment 2.0 second after touchdown							
	Stabilized Landing	.6	1276	1079	84.48	81.30	26.75	51.12
		.4	1644	1446	87.96	85.20	19.49	46.63
		.2	2662	2422	90.98	86.93	10.08	41.50
	Wet Runway		3352	2896	80.83	90.18	7.60	39.08
	Touchdown Profile	.6	1348	1078	79.97	79.22	26.74	47.46
		.4	1728	1446	83.68	82.44	19.12	43.78
		.2	2776	2422	87.25	85.03	10.17	38.79
4c	No Spoilers/Drag Devices							
	Stabilized Landing	.6	1480	1387	90.24	86.96	19.75	46.45
		.4	2040	1856	90.98	87.22	13.77	43.31
		.2	Wheel	Locks	Up, Would	Not	Run	
	Wet Runway		Wheel	Locks	Up, Would	Not	Run	
4d	60% Effective Spoilers							
	Stabilized Landing	.6	1210	1034	85.45	84.20	29.04	49.19
		.4	1643	1446	88.01	86.23	19.38	45.88
		.2	2819	2548	90.48	87.64	9.74	40.52
	Wet Runway		3704	3135	84.64	90.91	6.73	39.16
4e	40% Effective Spoilers							
	Stabilized Landing	.6	1313	1118	85.15	85.88	27.44	47.68
		.4	1794	1565	87.24	86.64	18.10	45.20
		.2	3122	2765	88.67	86.70	9.51	38.46
	Wet Runway		4490	3462	77.10	91.61	6.29	38.30
4f	120% Engine Idle Thrust							
	Stabilized Landing	.6	1067	920	86.22	82.89	25.34	50.67
		.4	1445	1293	89.48	86.60	17.06	45.92
		.2	2492	2302	92.38	88.56	8.36	41.18
	Wet Runway		3265	2767	84.75	88.90	6.36	35.22
4g	80% Engine Idle Thrust							
	Stabilized Landing	.6	1063	907	85.32	82.40	32.08	50.94
		.4	1430	1268	88.67	84.93	21.71	46.72
		.2	2419	2226	92.02	87.22	10.70	41.60
	Wet Runway		3128	2649	84.69	87.52	8.36	34.34
5a	150% Nominal Pressure Application Rate							
	Stabilized Landing	.6	1050	913	86.95	84.30	25.80	49.92
		.4	1425	1280	89.82	86.70	17.04	46.09
		.2	2444	2263	92.59	88.76	8.19	41.52
	Wet Runway		3295	2722	82.61	82.24	7.84	27.43
	Touchdown Profile	.6	1191	913	76.66	79.38	24.26	48.68
		.4	1519	1280	84.27	84.29	16.67	44.50
		.2	2529	2263	89.48	87.24	8.10	39.23

Table 19.—737 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_B	η_D	SI	CI
5b	50% Nominal Pressure Application Rate							
	Stabilized Landing	.6	1076	913	84.85	82.80	25.36	50.46
		.4	1442	1280	88.77	85.94	16.84	46.32
		.2	2458	2263	92.07	88.20	8.24	41.42
	Wet Runway		3274	2722	83.14	81.84	7.86	27.99
	Touchdown Profile	.6	1275	913	71.61	75.90	21.52	51.85
		.4	1549	1280	82.63	82.94	16.17	45.65
		.2	2518	2263	89.87	87.76	8.32	40.04
5c	Nominal Rate at 2.0 seconds From Touchdown							
	Stabilized Landing	.6	1003	852	84.94	61.65	23.67	59.05
		.4	1355	1197	88.34	74.50	16.91	54.18
		.2	2688	2131	79.27	83.10	10.77	45.47
	Wet Runway		Wheel Locks Up, Would Not Run					
	Touchdown Profile	.6	992	852	85.89	70.06	21.60	56.62
		.4	1346	1197	88.93	75.42	14.64	51.75
		.2	2320	2131	91.85	81.42	7.42	45.02
5d	Nominal Rate at 4.0 Seconds From Touchdown							
	Stabilized Landing	.6	977	794	81.27	55.96	17.79	64.17
		.4	1270	1119	88.11	64.59	12.00	60.00
		.2	2532	2006	79.25	76.63	7.25	49.93
	Wet Runway		2767	1920	69.29	75.40	7.49	44.46
	Touchdown Profile	.6	938	794	84.65	58.35	17.63	63.40
		.4	1268	1119	88.25	66.08	12.42	57.60
		.2	2198	2006	91.26	75.93	6.74	48.76
5e	75% of Full Metered Pressure							
	Stabilized Landing	.6	1074	913	85.01	82.75	24.98	50.96
		.4	1440	1280	88.89	85.90	16.65	46.60
		.2	2456	2263	92.14	88.15	8.10	41.80
	Wet Runway		3212	2722	84.74	88.88	6.40	34.54
5f	50% of Full Metered Pressure							
	Stabilized Landing	.6	1237	913	73.81	72.16	13.67	64.50
		.4	1491	1280	85.85	83.70	14.85	49.76
		.2	2528	2263	89.52	84.36	7.31	45.79
	Wet Runway		3242	2722	83.96	86.44	5.25	43.84
1a	10 Knot Wind							
	Stabilized Landing	.6	869	755	86.88	82.62	21.60	50.82
		.4	1163	1055	90.71	85.02	14.31	46.81
		.2	1954	1851	94.73	87.78	7.08	41.36
	Wet Runway		2296	1968	85.71	87.82	6.13	36.71
1b	20 Knot Wind							
	Stabilized Landing	.6	688	595	86.48	81.08	17.46	52.47
		.4	922	829	89.91	84.34	11.60	47.80
		.2	1522	1440	94.61	86.90	5.86	42.00
	Wet Runway		1622	1401	86.37	87.56	5.51	39.52

Table 19.—737 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_e	η_D	SI	CI
1c	±10 Knot Wind							
	Stabilized Landing	.6	1268	1073	84.62	85.30	27.80	48.66
		.4	1130	1506	87.05	86.83	19.44	45.64
		.2	2996	267[illegible]	89.75	89.26	9.34	41.05
	Wet Runway		4417	368[illegible]	83.41	89.05	6.38	32.36
2a	Hot Day - High Altitude							
	Stabilized Landing	.6	1084	926	85.42	83.39	26.19	49.84
		.4	1471	1309	88.[illegible]	86.17	17.29	46.25
		.2	2585	2567	91.57	88.14	9.10	39.52
	Wet Runway		3552	2974	83.73	89.52	6.44	34.50
2b	Cold Day - Sea Level							
	Stabilized Landing	.6	1035	897	86.57	83.43	24.62	50.23
		.4	1384	1241	89.67	86.47	16.24	49.98
		.2	2304	2151	92.49	88.27	7.90	41.14
	Wet Runway		2843	2452	86.28	87.94	6.12	34.66
3a	Rough Surface Runway							
	Stabilized Landing	.6	1112	913	82.10	77.02	20.64	55.57
		.4	1484	1280	86.25	82.06	14.24	50.70
		.2	2462	2263	91.92	87.54	7.60	43.92
	Wet Runway		3241	2722	85.58	87.05	7.94	39.62
1a	High Fade Brake							
	Stabilized Landing	.6	1057	913	86.87	83.78	25.63	50.02
		.5	1207	1068	88.07	85.32	21.37	47.94
		.4	1430	1280	89.91	86.19	16.92	46.18
1b	Low Fade Brake							
	Stabilized Landing	.6	1051	913	86.87	84.93	26.02	49.46
		.5	1206	1065	88.14	85.76	21.47	47.70
		.4	1426	1280	89.76	86.12	16.92	46.22
1c	Torque Peaking to 150% of Running							
	Stabilized Landing	.6	1060	913	86.13	83.91	25.65	49.88
		.4	1436	1280	89.14	86.31	16.88	46.10
		.2	2454	2263	92.22	87.62	8.24	41.58
	Wet Runway		3212	2722	84.74	86.06	6.91	31.93
1d	No Torque Peaking							
	Stabilized Landing	.6	1049	913	87.04	85.46	26.10	49.35
		.4	1422	1280	90.01	86.93	17.10	45.52
		.2	2433	2263	93.01	89.60	8.59	39.78
	Wet Runway		3223	2722	84.46	85.44	7.32	29.66
1e	Torque Response Break Point 150% Nominal							
	Stabilized Landing	.6	1034	913	88.30	86.71	27.55	47.48
		.4	1410	1280	90.78	89.31	18.15	45.52
		.2	2448	[illegible]	92.99	89.97	8.76	38.54
1f	Torque Response Break Point 50% Nominal							
	Stabilized Landing	.6	1085	913	89.15	[illegible]	24.66	51.58
		.4	1464	1280	87.43	83.96	16.11	48.18
		.2	2486	[illegible]	90.96	[illegible]	7.97	42.68

Table 19.—737 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_p	SI	CI
1g	Torque Gain 120% of Nominal							
	Stabilized Landing	.6	1066	913	85.65	83.94	26.28	49.64
		.4	1432	1280	89.39	85.45	17.02	46.16
		.2	2465	2263	91.81	88.10	8.00	41.88
	Wet Runway		3191	2722	85.30	91.14	5.76	40.02
1h	Torque Gain 80% of Nominal							
	Stabilized Landing	.6	1061	913	86.05	83.56	24.23	50.82
		.4	1435	1280	89.20	87.50	16.86	46.23
		.2	2474	2263	91.47	88.32	8.54	40.76
	Wet Runway		3220	2722	84.53	90.40	6.30	35.54
1i	Variable Torque Gain T = F (p)[5]							
	Stabilized Landing	.6	1068	913	85.49	84.38	25.94	49.88
		.4	1443	1280	88.70	85.73	16.98	46.72
		.2	2464	2263	91.84	87.40	8.37	41.82
	Wet Runway		3238	2722	84.06	87.62	6.50	34.50
1j	Linear Torque Gain T = F(p)							
	Stabilized Landing	.6	1054	913	86.62	84.46	25.91	49.76
		.4	1432	1280	89.39	87.44	17.18	45.74
		.2	2464	2263	91.84	89.10	8.62	40.43
	Wet Runway		3599	2722	75.63	89.78	6.77	32.97
2a	Tire Inflation Pressure 120% of Nominal							
	Stabilized Landing	.6	1192	913	76.59	75.17	15.14	69.98
		.4	1612	1280	79.40	76.98	9.37	67.14
		.2	2680	2263	84.44	79.77	4.42	62.22
2b	Tire Inflation Pressure 80% of Nominal							
	Stabilized Landing	.6	1014	913	90.04	89.24	37.58	29.60
		.4	1375	1280	95.39	91.50	25.90	25.48
		.2	2387	2263	94.81	92.86	12.72	22.06
2c	50% Worn Tire							
	Stabilized Landing	.6	1059	913	86.21	84.58	20.97	49.64
		.4	1430	1280	89.51	87.00	13.47	45.78
		.2	2458	2263	92.07	89.04	6.66	40.52
	Wet Runway		3255	2722	83.63	83.63	6.56	27.92
2d	80% Worn Tire							
	Stabilized Landing	.6	1064	913	85.81	85.26	16.64	50.42
		.4	1434	1280	89.26	85.85	10.58	46.70
		.2	2455	2263	92.18	88.93	5.18	41.08
	Wet Runway		3248	2722	83.81	85.88	5.32	29.12
2e	Low Tire Heating							
	Stabilized Landing	.6	990	913	92.22	93.34	32.60	41.84
		.4	1352	1280	94.67	95.01	21.18	38.00
		.2	2356	2263	96.05	95.84	10.00	34.61
	Wet Runway		3255	2722	83.50	84.96	18.21	14.78
2f	Flat $\mu - \sigma$ peak							
	Stabilized Landing	.6	974	913	93.74	95.46	44.19	25.92
		.4	1326	1280	96.55	98.24	27.74	23.89
		.2	2312	2263	97.88	98.96	14.58	20.08
	Wet Runway		3102	2722	87.74	94.46	15.95	13.44

Table 19.—737 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_B	η_D	SI	CI
3a	Maximum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	[illegible]	913	86.79	84.42	25.62	50.04
		.4	1432	1280	89.39	85.42	16.52	47.40
		.2	2442	2263	92.67	88.74	8.41	40.89
3b	Minimum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	1051	913	86.87	84.90	25.98	49.38
		.4	1426	1280	89.76	86.41	16.88	46.08
		.2	2443	2263	92.63	88.42	8.34	41.14
3c	Maximum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	1056	913	86.46	83.74	25.62	49.99
		.4	1426	1280	89.76	86.31	16.90	46.18
		.2	2444	2263	92.59	88.56	8.43	40.68
3d	Minimum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	1060	913	86.15	83.64	25.90	50.11
		.4	1430	1280	89.51	85.84	16.84	46.43
		.2	2446	2263	92.52	87.86	8.48	40.93
3e	Vertical Stiffness 120% of Nominal							
	Stabilized Landing	.6	1064	913	85.81	84.14	25.74	49.48
		.4	1432	1280	89.39	86.62	17.13	45.58
		.2	2458	2265	92.07	89.18	8.44	40.44
	Wet Runway		3224	2722	84.45	86.18	7.24	30.05
3f	Vertical Stiffness [illegible] of Nominal							
	Stabilized Landing	.6	1060	913	86.13	84.60	26.04	49.68
		.4	1434	1280	89.26	86.36	17.10	45.70
		.2	2458	2263	92.07	89.04	8.51	40.28
	Wet Runway		3246	2722	85.86	84.46	7.58	28.74
3g	Vertical Damping 120% of Nominal							
	Stabilized Landing	.6	1063	913	85.89	84.76	26.02	49.54
		.4	1438	1280	89.01	86.14	16.93	45.95
		.2	2460	2263	91.66	89.03	8.42	40.48
	Wet Runway		3247	2722	83.85	84.42	7.57	28.73
	Mu Steps		1379			76.29	18.48	48.29
3h	Vertical Damping 80% of Nominal							
	Stabilized Landing	.6	1061	913	86.05	84.16	25.90	49.76
		.4	1434	1280	89.26	86.17	17.02	45.78
			2463	2263	91.88	88.76	8.44	40.41
	Wet Runway		3256	2722	83.60	83.55	7.80	27.77
	Mu Steps		1379			76.04	18.76	48.15
1a	Decrease Line Diameter 50%							
	Stabilized Landing	.6	1105	913	82.62	78.15	26.74	52.35
		.4	1481	1280	86.45	81.86	18.10	47.67
		.2	2500	2263	90.52	86.47	9.08	43.41
1b	Increase Line Diameter 50%							
	Stabilized Landing	.6	[illegible]	913	82.70	[illegible]	[illegible]	[illegible]
		.4	[illegible]	1280	86.60	[illegible]	[illegible]	48.60
		.2	[illegible]	2263	90.74	[illegible]	[illegible]	[illegible]

Table 19.—737 Sens`'`ivity Test Data (Concluded)

CONDITION	DESCRIPTION	MU	X_A	X_P	$\dot{\eta}_e$	η_B	SI	CI
1c	Move Dynamic Break Point Out 150% of Nominal							
	Stabilized Landing	.6	1057	913	86.79	84.53	29.75	48.75
		.4	1430	1280	89.61	86.81	19.78	44.33
		.2	2480	2263	91.25	89.17	10.12	38.30
1d	Move Dynamic Break Point in 50% of Nominal							
	Stabilized Landing	.6	1120	913	81.56	75.05	26.63	49.93
		.4	1485	1280	86.31	82.24	17.87	48.96
		.2	2525	2263	89.62	85.55	8.92	43.54
1e	Insert 20% Restriction in Return Line							
	Stabilized Landing	.6	1072	913	85.17	80.95	28.66	49.47
		.4	1449	1280	88.54	84.63	19.19	45.22
		.2	2487	2263	91.18	88.62	9.85	39.70
	Mu Steps		1501			68.05	16.92	83.71
1f	Increase Brake Volume by 10 in ^{3}							
	Stabilized Landing	.6	1090	913	83.76	79.64	27.19	52.10
		.4	1469	1280	87.13	85.16	18.25	47.92
		.2	2472	2263	91.51	88.95	9.31	42.50
1g	Increase Brake p-V Gain							
	Stabilized Landing	.6	1022	915	89.33	87.61	29.56	45.55
		.4	1402	1280	91.30	89.47	19.58	41.50
		.2	2463	2263	91.88	89.73	9.90	3492

Table 20.—747 Baseline Braking Data

Condition	Mu	X_A	X_p	η_s	η_D	SI	CI
Test 2:							
Touchdown dynamics	0.6	2138	1709	79.93	87.26	23.22	47.63
	0.5	2455	1983	80.77	86.62	18.92	47.34
	0.4	2910	2382	81.85	88.12	15.67	44.43
	0.3	3661	3015	82.35	88.30	11.50	43.94
	0.2	5094	4183	82.10	87.90	7.50	42.46
	0.1	9086	7189	79.12	85.54	3.12	46.06
Test 3:							
Stabilized landing	0.6	1905	1709	89.71	89.58	25.96	49.16
	0.5	2206	1983	89.89	38.96	21.44	47.81
	0.4	2630	2382	90.57	89.06	16.50	47.28
	0.3	3308	3015	91.14	88.64	11.59	47.28
	0.2	4598	4183	90.97	90.92	7.40	44.98
	0.1	8222	7189	87.43	89.88	2.74	48.64
	0.05	15916	12255	76.99	84.05	5.37	59.85
Test 4:							
Mu steps	0.1 to 0.5	2850	---	---	68.90	12.34	59.78
Test 5:							
Wet runway	0.05 to 0.5	6809	4183	61.43	83.02	4.26	51.82

Table 21.—747 Sensitivity Test Data

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_b	SI	CI
1a	Maximum Landing Weight							
	Stabilized Landing	.6	2090	1896	90.71	91.57	32.52	48.59
		.4	2891	2637	91.21	89.45	20.25	46.98
		.2	5040	4605	91.36	89.55	8.98	45.17
	Wet Runway		7798	6842	87.74	83.11	4.84	51.12
1b	Minimum Landing Weight							
	Stabilized Landing	.6	1528	1355	88.67	88.84	15.58	48.85
		.4	2137	1899	88.86	86.32	9.72	48.68
		.2	3774	3381	89.58	90.67	4.65	48.96
	Wet Runway		5050	4357	86.28	84.18	2.92	51.95
2a	High Center of Gravity							
	Stabilized Landing	.6	TEST	NOT	RUN			
		.4						
		.2						
	Wet Runway							
2b	Low Center of Gravity							
	Stabilized Landing	.6	TEST	NOT	RUN			
		.4						
		.2						
	Wet Runway							
2c	Forward Center of Gravity							
	Stabilized Landing	.6	1954	1760	90.07	89.76	25.27	48.46
		.4	2709	2451	90.47	89.20	15.71	47.65
		.2	4739	4297	90.67	90.70	7.11	44.92
	Wet Runway		7005	6069	86.64	81.67	4.02	52.48
2d	Aft Center of Gravity							
	Stabilized Landing	.6	1851	1666	90.00	90.17	27.37	48.67
		.4	2577	2324	90.18	88.47	16.90	47.81
		.2	4512	4088	90.60	90.37	7.59	45.49
	Wet Runway		6809	5849	85.90	81.19	4.27	52.92
3a	Brakes on Speed + 10%							
	Stabilized Landing	.6	2112	1912	90.53	90.61	27.07	48.22
		.4	2910	2648	90.99	89.42	16.84	47.41
		.2	5036	4580	90.94	91.12	7.69	44.51
	Wet Runway		7676	6632	86.40	78.61	3.83	54.73
3b	Brakes on Speed + 20%							
	Stabilized Landing	.6	2334	2132	91.34	91.43	27.88	47.79
		.4	3201	2931	91.56	90.10	17.17	47.34
		.2	5469	4990	91.24	90.84	7.70	45.21
	Wet Runway		8440	7305	86.55	76.94	3.62	55.98
4a	Drag Device Deployment 1.0 Second After Touchdown							
	Stabilized Landing	.6	2082	1872	89.91	86.62	23.51	51.48
		.4	2855	2562	89.74	86.24	15.05	49.67
		.2	4814	4387	91.13	87.63	7.18	45.70
	Wet Runway		7060	6026	85.35	80.57	4.07	52.46
	Touchdown Profile	.6	2218	1872	84.40	87.68	24.91	47.78
		.4	3054	[illegible]	83.89	85.86	15.74	43.21
		.2	5215	4587	89.12	81.95	1.46	41.76

Table 21.—747 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	$\bar{\eta}_e$	η_p	SI	$\bar{GI}$
4b	Drag Device Deployment 2.0 second after touchdown							
	Stabilized Landing	.6	2168	1969	90.77	85.78	21.82	52.25
		.4	2917	2657	91.09	84.3	14.95	49.74
		.2	4920	4481	91.08	86.62	6.90	47.05
	Wet Runway		7188	6120	85.14	78.58	3.95	52.98
	Touchdown Profile	.6	2389	1968	82.38	84.92	22.43	45.87
		.4	3137	2657	84.70	85.[illegible]2	15.22	43.62
		.2	5279	4481	84.88	87.46	7.34	41.20
4c	No Spoilers/Drag Devices							
	Stabilized Landing	.6	2507	2284	91.10	93.97	26.53	46.82
		.4	3491	3176	90.97	92.5[illegible]	12.75	47.[illegible]7
		.2	6263	5559	88.75	90.37	5.46	47.81
	Wet Runway		10103	8411	83.85	79.38	2.70	56.59
4d	60% Effective Spoilers							
	Stabilized Landing	.6	2085	1887	90.50	91.85	24.06	48.04
		.4	2908	2629	90.40	90.20	14.84	47.97
		.2	5135	4616	89.89	89.27	6.74	45.76
	Wet Runway		7885	6679	84.70	75.91	3.48	56.51
4e	40% Effective Spoilers							
	Stabilized Landing	.6	2199	1997	90.81	[illegible]	[illegible].74	47.87
		.4	3066	2781	90.70	9[illegible]	4.20	47.30
		.2	5464	4880	89.31	87.[illegible]	6.08	48.24
	Wet Runway		8607	7081	82.27	71.[illegible]	2.97	60.76
4f	120% Engine Idle Thrust							
	Stabilized Landing	.6	1916	1728	90.18	91.83	25.75	49.33
		.4	2661	2419	90.90	90.20	16.05	47.92
		.2	4702	4298	91.40	90.79	7.12	46.21
	Wet Runway		72[illegible]	6201	85.58	76.[illegible]0	3.69	57.54
4g	80% Engine Idle Thrust							
	Stabilized Landing	.6	1868	1690	90.47	92.18	26.03	48.15
		.4	2580	2346	90.93	89.39	15.97	48.10
		.2	4438	4075	91.82	91.94	7.06	45.83
	Wet Runway		6543	5728	87.54	76.85	3.65	57.54
5a	150% Nominal Pressure Application Rate							
	Stabilized Landing	.6	1868	1708	91.43	94.20	26.01	47.95
		.4	2601	2382	91.58	92.90	16.06	46.79
		.2	4562	4183	91.69	93.30	6.97	45.65
	Wet Runway		6750	5961	88.31	87.28	3.95	52.16
	Touchdown Profile	.6	2124	1708	80.41	90.38	23.54	45.86
		.4	2906	2382	81.[illegible]	90.32	15.24	44.56
		.2	5079	4185	82.36	91.70	7.22	42.24

Table 21.—747 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_B	SE	ET
5b	50% Nominal Pressure Application Rate							
	Stabilized Landing	.6	1907	1708	89.56	92.41	25.63	48.30
		.4	2630	2382	90.57	92.02	16.07	47.10
		.2	4994	4183	91.05	92.83	7.06	45.38
	Wet Runway		6825	5961	87.34	86.47	3.96	52.55
	Touchdown Profile	.6	2168	1708	78.78	87.36	21.07	49.53
		.4	2890	2382	82.42	91.06	14.65	46.17
		.2	5060	4183	82.66	91.08	6.90	43.18
5c	Nominal Rate at 2.0 seconds From Touchdown							
	Stabilized Landing	.6	1833	1575	85.92	74.77	21.62	55.39
		.4	2548	2205	86.54	75.94	13.80	52.96
		.2	4593	3913	85.19	66.02	11.80	32.55
	Wet Runway		6507	5536	86.08	58.59	9.15	21.05
	Touchdown Profile	.6	1943	1575	81.06	81.48	21.11	52.40
		.4	2684	2205	82.15	84.70	13.73	49.47
		.2	4699	3913	83.27	89.73	6.38	45.33
5d	Nominal Rate at 4.0 Seconds From Touchdown							
	Stabilized Landing	.6	1735	1501	86.51	66.47	19.23	59.75
		.4	2477	2108	86.86	70.26	12.91	55.84
		.2	4039	3762	93.14	75.28	6.29	49.17
	Wet Runway		6360	5114	80.41	52.98	9.81	21.67
	Touchdown Profile	.6	1850	1501	81.14	72.18	18.82	57.19
		.4	2559	2108	82.58	77.37	12.41	53.83
		.2	4520	3762	83.23	85.48	5.97	47.85
5e	75% Of Full Metered Pressure							
	Stabilized Landing	.6	1885	1708	90.61	95.57	25.51	48.65
		.4	2643	2382	90.12	90.20	15.72	48.24
		.2	4566	4183	91.61	91.68	7.05	45.99
	Wet Runway		6847	5961	87.06	78.03	3.47	58.06
5f	50% Of Full Metered Pressure							
	Stabilized Landing	.6	2234	1108	[illegible]	74.12	13.84	65.43
		.4	2680	[illegible]	88.88	91.22	15.35	49.14
		.2	4559	4183	91.75	91.44	1.20	45.46
	Wet Runway		6497	5961	91.75	85.38	3.90	53.80
1a	10 Knot Wind							
	Stabilized Landing	.6	1751	1478	84.40	90.87	23.33	48.89
		.4	2407	2056	85.41	89.58	14.47	48.15
		.2	4098	3588	[illegible]	90.89	6.21	46.91
	Wet Runway		5112	4623	[illegible]	76.13	3.37	58.50
1b	20 Knot Wind							
	Stabilized Landing	.6	1631	1248	[illegible]	90.83	20.14	48.91
		.4	2248	1730	[illegible]	88.09	12.70	48.79
		.2	[illegible]	[illegible]	[illegible]	[illegible]	5.56	47.14
	Wet Runway		[illegible]	[illegible]	[illegible]	81.04	[illegible]	54.49

Table 21.—747 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_A	η_P	SI	CI
1c	10 Knot Wind							
	Stabilized Landing	.6	2048	1939	94.67	92.52	28.46	48.58
		.4	2852	2708	94.95	90.54	17.68	47.61
		.2	5017	4778	94.11	91.77	7.77	46.11
	Wet Runway		8486	7587	89.41	72.49	3.51	59.93
2a	Hot Day - High Altitude							
	Stabilized Landing	.6	1868	1666	89.18	91.81	27.66	49.12
		.4	2610	2354	90.19	90.47	17.29	47.96
		.2	4696	4270	90.92	91.86	7.82	45.31
	Wet Runway		7853	6527	83.11	94.77	3.71	58.72
2b	Cold Day - Sea Level							
	Stabilized Landing	.6	1953	1775	90.88	91.72	23.41	48.32
		.4	2670	2424	90.78	89.83	14.41	47.94
		.2	4460	4066	91.16	89.99	6.28	46.56
	Wet Runway		6095	5323	87.33	74.25	3.47	57.99
3a	Rough Surface Runway							
	Stabilized Landing	.6	1939	1708	88.08	91.29	23.37	51.67
		.4	2675	2382	89.04	90.45	14.89	49.51
		[illegible]	4644	4185	90.07	91.82	6.77	46.88
	Wet Runway		6850	5961	87.02	88.60	3.99	51.79
1a	High Fade Brake							
	Stabilized Landing	.6	1893	1709	90.28	92.50	26.12	48.45
		.5	2190	1983	90.55	91.19	21.16	47.73
		.4	2627	2382	90.67	90.12	16.11	47.91
1b	Low Fade Brake							
	Stabilized Landing	.6	1886	1709	90.62	92.51	25.99	48.54
		.5	2191	1983	90.51	91.01	21.13	47.93
		.4	2625	2382	90.74	90.76	16.26	47.26
1c	Torque Peaking to 150% of Running							
	Stabilized Landing	.6	1906	1709	89.66	90.69	25.56	49.65
		.4	2645	2382	90.06	88.42	15.85	48.86
		.2	4616	4185	90.62	90.17	7.05	46.38
	Wet Runway		6883	5961	86.60	76.38	3.67	57.37
1d	No Torque Peaking							
	Stabilized Landing	.6	1884	1709	90.71	92.79	26.12	48.94
		.4	2606	2382	91.40	92.28	16.56	46.88
		.2	4584	4183	91.25	92.16	7.40	45.32
	Wet Runway		7012	5961	85.01	74.70	3.47	59.67
1e	Torque Response Break Point 150% Nominal							
	Stabilized Landing	.6	1870	1709	91.39	94.54	26.89	48.19
		.4	2510	2382	92.68	94.92	17.17	45.75
		[illegible]	4461	4183	93.77	95.47	7.52	44.58
1f	Torque Response Break Point 50% Nominal							
	Stabilized Landing	.6	1908	1709	89.57	91.02	25.76	49.84
		.4	2686	[illegible]	86.68	87.86	15.89	49.05
		.2	4110	4185	87.69	85.78	6.58	49.64

Table 21.—747 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_e	η_p	SI	CI
1g	Torque Gain 120% of Nominal							
	Stabilized Landing	.6	1930	1709	88.55	88.09	25.07	50.73
		.4	2711	2382	87.86	85.90	15.43	50.15
		.2	4816	4183	86.86	83.51	5.99	52.03
	Wet Runway		7349	5961	91.11	67.38	3.06	62.89
1h	Torque Gain 80% of Nominal							
	Stabilized Landing	.6	1882	1709	90.81	94.76	25.08	51.05
		.4	2620	2382	90.92	90.03	16.44	47.85
		.2	4572	4183	91.49	88.85	7.31	46.64
	Wet Runway		6703	5961	86.35	74.98	3.86	56.94
1i	Variable Torque Gain $T = F(p)$[5]							
	Stabilized Landing	.6	1888	1709	90.52	93.57	26.28	48.41
		.4	2657	2382	89.82	89.83	16.04	47.54
		.2	4704	4183	88.92	90.24	6.50	48.21
	Wet Runway		[illegible]	5961	82.55	85.70	3.61	53.76
1j	Linear Torque Gain $T = F(p)$							
	Stabilized Landing	.6	1848	1709	90.04	92.71	25.56	48.77
		.4	2604	2382	91.47	93.70	16.49	46.44
		.2	4491	4183	93.14	95.40	7.67	42.81
	Wet Runway		6409	5961	93.00	94.00	5.02	42.74
2a	Tire Inflation Pressure 120% of Nominal							
	Stabilized Landing	.6	1957	1709	87.33	91.61	18.28	65.83
		.4	2785	2382	85.53	86.31	10.64	64.54
		.2	4933	4183	84.80	83.97	4.51	62.74
2b	Tire Inflation Pressure 80% of Nominal							
	Stabilized Landing	.6	1896	1709	90.28	92.55	35.52	29.51
		.4	2563	2382	92.94	97.10	24.47	25.94
		.2	4473	4183	95.52	98.33	11.19	25.53
2c	50% Worn Tire							
	Stabilized Landing	.6	1902	1709	89.85	91.03	25.07	50.45
		.4	2652	2382	89.82	88.10	15.56	49.22
		.2	4688	4183	89.23	85.77	6.50	49.15
	Wet Runway		7209	5961	82.69	68.53	3.18	61.51
2d	80% Worn Tire							
	Stabilized Landing	.6	1905	1709	89.71	90.58	25.53	49.95
		.4	2655	2382	89.72	88.59	15.85	48.94
		.2	4686	4183	89.77	86.20	6.45	50:20
	Wet Runway		7185	5961	82.96	70.22	3.37	60.97
2e	Low Tire Heating							
	Stabilized Landing	.6	1813	1709	94.76	99.30	28.12	45.74
		.4	2504	2382	95.70	99.76	18.33	42.38
		.2	4405	4183	94.96	100.00	7.93	42.11
	Wet Runway		6554	5961	90.95	94.95	4.50	47.83
2f	Flat $\mu - \sigma$ peak							
	Stabilized Landing	.6	1191	1709	95.06	[illegible]	39.96	29.47
		.4	2468	2382	96.52	101.59	26.16	25.42
		.2	4365	4183	95.83	[illegible]	9.12	35.66
	Wet Runway		6556	5961	90.92	[illegible]	7.14	51.79

Table 21.—747 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_D	SI	CI
3a	Maximum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	1908	1709	89.57	90.20	24.67	49.48
		.4	2663	2382	89.45	87.84	15.38	48.51
		.2	4690	4183	89.19	86.20	6.69	47.70
3b	Minimum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	1896	1709	90.14	91.75	24.72	49.79
		.4	2658	2382	89.64	88.59	14.94	50.12
		.2	4646	4183	90.05	88.30	6.55	48.12
3c	Maximum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	1899	1709	89.99	90.63	25.75	48.08
		.4	2630	2382	90.87	90.14	16.20	46.79
		.2	4555	4183	91.88	93.15	7.22	44.66
3d	Minimum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	TEST	NOT	RUN			
		.4						
		.2						
3e	Vertical Stiffness 120% of Nominal							
	Stabilized Landing	.6	1886	1709	90.62	93.33	25.97	47.79
		.4	2621	2382	90.88	91.98	16.10	46.91
		.2	4573	4183	91.47	92.64	7.12	44.75
	Wet Runway		6740	5961	88.44	88.45	4.04	51.40
3f	Vertical Stiffness 80% of Nominal							
	Stabilized Landing	.6	1881	1709	90.86	93.42	26.04	47.83
		.4	2615	2382	91.09	92.47	16.51	47.16
		.2	4570	4183	91.53	92.27	7.05	45.44
	Wet Runway		6784	5961	87.87	87.26	3.87	52.90
3g	Vertical Damping 120% of Nominal							
	Stabilized Landing	.6	1882	1709	90.81	92.80	25.84	48.02
		.4	2612	2382	91.19	92.39	16.07	47.19
		.2	4572	4183	91.49	92.28	7.05	45.30
	Wet Runway		6825	5961	87.34	84.57	3.84	53.56
	Mu Steps		2676			79.51	16.30	48.93
3h	Vertical Damping 80% of Nominal							
	Stabilized Landing	.6	1887	1709	90.57	93.24	26.01	47.96
		.4	2623	2382	90.81	91.37	15.97	47.51
		.2	4569	4183	91.55	92.79	7.08	45.17
	Wet Runway		6784	5961	87.87	86.86	3.91	52.82
	Mu Steps		2706			76.02	14.73	51.93
1a	Decrease Line Diameter 50%							
	Stabilized Landing	.6	TEST	NOT	RUN			
		.4						
		.2						
1b	Increase Line Diameter 50%							
	Stabilized Landing	.6	[illegible]	1709	91.54	96.10	26.41	47.05
		.4	2591	[illegible]	91.73	94.50	16.45	45.97
		.2	4547	4183	91.99	94.67	7.09	45.60

Table 21.—747 Sensitivity Test Data (Concluded)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_e	η_B	SI	CI
1c	Move Dynamic Break Point Out 150% of Nominal							
	Stabilized Landing	.6	1975	1709	91.15	94.41	26.16	47.40
		.4	2591	2382	91.93	93.73	16.51	46.60
		.2	4510	4183	92.75	93.40	7.59	45.19
1d	Move Dynamic Break Point in 50% of Nominal							
	Stabilized Landing	.6	1896	1709	90.14	92.63	[illegible]5.40	49.02
		.4	[illegible]	2382	89.55	90.22	15.81	47.69
		.2	4706	4183	88.89	89.50	6.66	47.71
1e	Insert 20% Restriction in Return Line							
	Stabilized Landing	.6	1920	1709	89.01	90.05	24.50	50.35
		.4	[illegible]674	2382	89.08	87.93	15.43	48.53
		.2	4872	4183	85.86	87.15	6.08	50.64
	Mu Steps		2511			67.18	11.50	60.16
1f	Increase Brake Volume by 10 in^3							
	Stabilized Landing	.6	1886	1709	90.62	[illegible]5.65	26.22	48.17
		.4	2634	2382	90.43	91.00	15.97	48.18
		.2	4681	4183	89.36	89.28	6.64	48.26
1g	Increase Brake p-V Gain							
	Stabilized Landing	.6	UNSTABLE,		TEST	NOT	RUN	
		.4						
		.2						

Table 22.—C-141 Baseline Braking Data

Condition	Mu	X_A	X_p	η_s	η_D	SI	CI
Test 2:							
Touchdown dynamics	0.6	2064	1227	59.46	55.84	27.95	40.98
	0.5*						
	0.4	2975	1693	56.91	50.24	23.49	29.45
	0.3*						
	0.2	6045	2897	47.9[illegible]	39.03	17.51	11.70
	0.1*						
Test 3:							
Stabilized landing	0.6	1841	1227	66.65	56.88	26.09	44.67
	0.5	2223	1418	63.79	55.30	23.06	40.32
	0.4	2752	1693	61.52	52.59	20.71	34.92
	0.3	3813	2123	55.68	40.97	19.26	25.23
	0.2	5650	2897	51.27	38.78	15.03	18.53
	0.1**						
Test 4:							
Mu steps	0.1 to 0.5	2451	---	---	53.20	20.98	38.35
Test 5:							
Wet runway	0.1150 to 0.5	5033	2996	59.53	41.91	17.84	21.14

* Test not run.

** System would not operate.

Table 23.—C-141 Sensitivity Test Data

CONDITION	DESCRIPTION	MU	X_A	X_P	η_a	η_b	SI	CI
1a	Maximum Landing Weight							
	Stabilized Landing	.6	[illegible]	1454	67.37	[illegible]	[illegible]	46.54
		.4	[illegible]	2001	64.[illegible]	55.64	[illegible]	40.94
		.2	[illegible]	3495	53.43	[illegible]	[illegible]	[illegible]
	Wet Runway		5142	3507	59.93	[illegible]	20.10	21.5[illegible]
1b	Minimum Landing Weight							
	Stabilized Landing	.6	[illegible]	858	51.93	[illegible]	[illegible]	[illegible]
		.4	[illegible]	1189	45.74	[illegible]	15.21	21.13
		.2	[illegible]	2054	44.65	[illegible]	9.20	7.18
	Wet Runway		[illegible]	2132	56.38	[illegible]	13.70	8.33
2a	High Center of Gravity							
	Stabilized Landing	.6	[illegible]	TEST	RUN			
		.4						
		.2						
	Wet Runway							
2b	Low Center of Gravity							
	Stabilized Landing	.6	TEST	NOT	RUN			
		.4						
		.2						
	Wet Runway							
2c	Forward Center of Gravity							
	Stabilized Landing	.6	1984	1276	64.31	54.25	25.14	42.02
		.4	2884	1759	60.99	51.55	20.58	32.37
		.2	5842	2998	51.31	38.71	14.41	18.16
	Wet Runway		5246	3087	58.84	41.82	17.91	18.29
2d	Aft Center of Gravity							
	Stabilized Landing	.6	[illegible]	1202	66.77	56.45	26.6[illegible]	44.58
		.4	2702	1660	61.43	53.36	20.15	36.27
		.2	5536	2845	51.35	38.72	15.25	19.35
	Wet Runway		49[illegible]	2947	59.36	41.85	18.41	20.85
3a	Brakes on Speed + 10%							
	Stabilized Landing	.6	2144	1471	68.61	[illegible]	26.15	46.15
		.4	3173	2009	63.31	54.16	[illegible]	36.66
		.2	6274	3362	53.58	[illegible]	15.69	[illegible]
	Wet Runway		[illegible]	3414	59.55	41.18	21.40	14.78
3b	Brakes on Speed + 20%							
	Stabilized Landing	.6	2466	1730	70.15	58.81	[illegible]	49.[illegible]
		.4	3580	2341	65.39	[illegible]	[illegible]	[illegible]
		.2	[illegible]	3832	55.93	[illegible]	16.08	[illegible]
	Wet Runway		[illegible]	[illegible]	60.21	40.[illegible]	[illegible]	14.[illegible]
4a	Drag Device Deployment 1.0 Second After Touchdown							
	Stabilized Landing	.6	[illegible]	1347	67.58	[illegible]	[illegible]	44.[illegible]
		.4	[illegible]	1817	62.39	[illegible]	[illegible]	[illegible]
		.2	[illegible]	3029	51.59	[illegible]	[illegible]	[illegible]
	Wet Runway		[illegible]	5102	[illegible]	[illegible]	[illegible]	[illegible]
	Touchdown Profile	.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 23.—C-141 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	T_P	η_e	η_B	SI	$\tilde{GI}$
4b	Drag Device Deployment 2.0 second after touchdown							
	Stabilized Landing	.6	2113	1447	68.48	55.66	26.87	42.80
		.4	3075	1920	63.47	51.07	22.91	31.50
		.2	5960	3182	52.55	39.13	16.20	16.87
	Wet Runway		5540	3206	57.87	40.02	21.61	12.47
	Touchdown Profile	.6	2254	1447	64.19	54.58	28.58	37.50
		.4	3228	1920	59.48	49.11	24.91	26.48
		.2	6789	3132	49.80	38.88	18.33	10.36
4c	No Spoilers/Drag Devices							
	Stabilized Landing	.6	2948	1842	62.48	54.46	24.09	39.90
		.4	4575	2550	55.78	44.84	22.60	27.62
		.2	Would Not Run					
	Wet Runway		Would Not Run					
4d	60% Effective Spoilers							
	Stabilized Landing	.6	2139	1399	65.40	55.64	24.82	45.00
		.4	3214	1934	60.17	49.95	21.38	31.94
		.2	6506	3521	51.04	37.38	14.64	18.19
	Wet Runway		Would Not Run					
4e	40% Effective Spoilers							
	Stabilized Landing	.6	2340	1512	64.61	57.60	23.93	44.45
		.4	3565	2091	58.65	48.07	21.25	31.65
		.2	7050	3596	51.00	40.12	14.87	16.54
	Wet Runway		Would Not Run					
4f	120% Engine Idle Thrust							
	Stabilized Landing	.6	1866	1236	66.23	56.79	26.60	42.93
		.4	2797	1709	61.10	50.73	20.89	33.63
		.2	5836	2944	50.44	37.58	14.80	18.17
	Wet Runway		5200	3047	58.60	40.40	19.01	17.05
4g	60% Engine Idle Thrust							
	Stabilized Landing	.6	1824	1218	66.77	56.61	26.68	43.01
		.4	2703	1677	62.04	51.22	20.80	34.55
		.2	5430	2849	52.47	37.51	14.82	19.00
	Wet Runway		4894	2911	59.48	40.30	17.48	21.40
5a	150% Nominal Pressure Application Rate							
	Stabilized Landing	.6	Test Not Run					
		.4						
		.2						
	Wet Runway							
	Touchdown Profile	.6						
		.4						
		.2						

Table 23.—C-141 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_B	η_{BA}	SI	GI
5b	50% Nominal Pressure Application Rate							
	Stabilized Landing	.6	TEST NOT RUN					
		.4						
		.2						
	Wet Runway							
	Touchdown Profile	.6						
		.4						
		.2						
5c	Nominal Rate at 2.0 seconds From Touchdown							
	Stabilized Landing	.6	TEST NOT RUN					
		.4						
		.2						
	Wet Runway							
	Touchdown Profile	.6						
		.4						
		.2						
5d	Nominal Rate at 4.0 Seconds From Touchdown							
	Stabilized Landing	.6	TEST NOT RUN					
		.4						
		.2						
	Wet Runway							
	Touchdown Profile	.6						
		.4						
		.2						
5e	75% of Full Metered Pressure							
	Stabilized Landing	.6	1772	1227	69.24	52.04	23.34	48.87
		.4	2796	1693	60.55	44.70	19.35	40.66
		.2	5900	2897	49.10	35.06	13.25	29.19
	Wet Runway		5367	2996	56.82	38.91	17.04	31.00
5f	50% of Full Metered Pressure							
	Stabilized Landing	.6	1421	1227	86.34	79.77	21.75	60.63
		.4	2588	1693	65.41	51.19	18.18	41.55
		.2	5915	2897	48.9[illegible]	34.73	11.59	34.15
	Wet Runway		5346	2996	56.04	36.84	13.44	40.92
1a	10 Knot Wind							
	Stabilized Landing	.6	1566	1039	66.34	53.98	25.11	41.22
		.4	2290	1430	62.28	48.85	20.44	31.[illegible]
		.2	4544	2428	53.43	36.86	15.45	18.10
	Wet Runway		[illegible]	2314	58.73	39.74	17.47	19.71
1b	20 Knot Wind							
	Stabilized Landing	.6	[illegible]	851	65.21	57.76	23.54	39.40
		.4	1874	1166	64.21	48.40	18.[illegible]	31.33
		.2	[illegible]	1959	55.30	[illegible]	15.06	17.84
	Wet Runway		[illegible]	1779	51.97	[illegible]	16.39	21.77

Table 23.—C-141 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_e	η_D	SI	CI
1c	±10 Knot Wind							
	Stabilized Landing	.6	2146	1415	65.95	57.97	27.68	46.49
		.4	3193	1957	61.29	52.07	22.32	34.99
		.2	6772	3366	49.70	38.07	15.71	19.37
	Wet Runway		6494	3697	57.02	39.90	20.99	13.37
2a	Hot Day - High Altitude							
	Stabilized Landing	.6	1715	1241	64.80	54.51	27.01	43.31
		.4	2830	1730	61.13	52.01	21.09	35.68
		.2	6127	3031	49.46	37.75	15.16	19.74
	Wet Runway		5636	3165	56.16	40.63	18.67	19.41
2b	Cold Day - Sea Level							
	Stabilized Landing	.6	1819	1206	66.30	55.02	26.81	40.65
		.4	2606	1642	63.00	50.91	20.65	33.64
		.2	5120	2724	53.20	37.27	14.51	18.37
	Wet Runway		4544	2740	60.30	39.97	17.73	19.73
3a	Rough Surface Runway							
	Stabilized Landing	.6	1883	1227	65.16	56.00	28.28	41.58
		.4	2762	1693	61.29	52.17	22.27	33.38
		.2	5717	2897	50.67	38.73	15.91	17.89
	Wet Runway		NOT	RUN				
1a	High Fade Brake							
	Stabilized Landing	.6	1837	1227	66.79	56.65	25.89	44.92
		.5	2222	1418	63.82	53.61	23.12	40.61
		.4	2736	1693	61.88	51.38	20.94	34.30
1b	Low Fade Brake							
	Stabilized Landing	.6	1837	1227	66.79	54.71	25.65	45.44
		.5	2223	1418	63.79	52.61	23.51	40.55
		.4	2743	1693	61.72	51.15	20.33	34.95
1c	Torque Peaking to 150% of Running							
	Stabilized Landing	.6	1820	1227	67.05	56.50	26.78	43.86
		.4	2728	1693	62.06	52.07	21.05	34.55
		.2	5645	2897	51.32	37.49	15.01	19.01
	Wet Runway		5060	2996	59.21	40.12	18.03	20.57
1d	No Torque Peaking							
	Stabilized Landing	.6	1835	1227	66.87	57.71	26.77	44.63
		.4	2733	1693	61.95	51.75	21.57	33.76
		.2	5661	2897	51.17	37.60	15.12	18.76
	Wet Runway		5083	2996	58.94	39.95	18.19	20.27
1e	Torque Response Break Point 150% Nominal							
	Stabilized Landing	.6	1868	1227	65.67	55.75	26.47	43.91
		.4	2777	1693	62.70	51.35	21.26	33.70
		.2	5547	2897	52.23	38.70	15.30	17.55
1f	Torque Response Break Point 50% Nominal							
	Stabilized Landing	.6	[illegible]	1227	64.99	54.5[illegible]	27.11	43.75
		.4	2792	1693	60.64	56.08	27.45	32.47
		.2	[illegible]	2877	56.82	[illegible]	15.29	18.47

Table 23.—C-141 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_p	SI	CI
1g	Torque Gain 120% of Nominal							
	Stabilized Landing	.6	1955	1277	62.76	53.54	29.14	42.55
		.4	3077	1693	55.02	39.08	24.94	28.80
		.2	5788	2897	50.05	37.09	15.60	18.27
	Wet Runway		5585	2996	55.63	28.60	21.63	12.10
1h	Torque Gain 80% of Nominal							
	Stabilized Landing	.6	1869	1227	65.65	53.05	23.48	45.91
		.4	2623	1693	64.54	54.97	18.21	39.76
		.2	5397	2897	53.68	37.48	14.07	19.89
	Wet Runway		4738	2996	63.23	45.01	17.90	19.65
1i	Variable Torque Gain T = F (p)[5]							
	Stabilized Landing	.6	1772	1227	69.23	57.88	28.30	40.20
		.4	2840	1693	59.61	45.61	24.48	28.25
		.2	5711	2897	50.75	39.55	16.78	14.56
	Wet Runway		5330	2996	56.21	39.47	22.82	9.30
1j	Linear Torque Gain T = F(p)							
	Stabilized Landing	.6	1955	1227	62.76	52.81	23.66	48.40
		.4	2768	1693	61.16	51.79	18.00	40.51
		.2	5195	2897	56.77	47.01	13.56	20.70
	Wet Runway		4603	2996	65.09	48.30	16.47	24.74
2a	Tire Inflation Pressure 120% of Nominal							
	Stabilized Landing	.6	1888	1227	64.99	53.44	22.22	55.06
		.4	2973	1693	56.95	47.70	19.36	38.06
		.2	6197	2897	46.75	35.41	14.88	13.16
2b	Tire Inflation Pressure 80% of Nominal							
	Stabilized Landing	.6	1751	1227	70.07	62.14	34.02	34.67
		.4	2547	1693	66.47	57.66	25.90	31.03
		.2	4882	2897	59.34	45.51	[illegible]	21.76
2c	50% Worn Tire							
	Stabilized Landing	.6	1845	1227	66.50	57.51	26.60	45.37
		.4	2767	1693	61.19	50.85	21.55	34.12
		.2	5697	2897	50.85	31.68	15.22	19.23
	Wet Runway		5134	2996	58.36	40.44	18.38	20.20
2d	80% Worn Tire							
	Stabilized Landing	.6	1882	1227	65.20	56.25	27.47	43.02
		.4	2792	1693	60.64	49.37	22.38	32.67
		.2	5743	2897	50.44	37.02	14.97	[illegible]
	Wet Runway		5153	2996	58.14	39.40	11.82	22.44
2e	Low Tire Heating							
	Stabilized Landing	.6	1670	1227	73.47	68.45	31.37	50.75
		.4	2342	1693	72.29	66.43	27.72	40.38
		.2	4102	2897	70.62	60.01	24.66	26.35
	Wet Runway		3950	2996	75.85	61.88	25.85	25.57
2f	Flat [illegible]							
	Stabilized Landing	.6	1618	1227	75.83	70.57	35.33	49.50
		.4	2266	1693	74.71	61.99	28.16	41.10
		.2	5951	2897	73.70	66.12	26.26	27.35
	Wet Runway		5105	2996	79.58	68.74	30.94	26.05

Table 23.—C-141 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_B	SI	CI
3a	Maximum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	1875	1227	65.44	55.25	27.57	41.82
		.4	2767	1693	61.19	50.55	21.79	33.54
		.2	5771	2897	50.20	36.88	14.73	19.20
3b	Minimum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	1863	1227	65.69	56.04	27.45	42.45
		.4	2805	1693	60.36	49.49	22.07	32.23
		.2	5745	2897	50.43	[illegible]	14.70	19.43
3c	Maximum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	1898	1227	64.65	54.47	27.63	41.26
		.4	2766	1693	61.21	50.75	21.81	32.83
		.2	5778	2897	50.14	36.83	15.07	17.38
3d	Minimum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	1866	1227	65.76	55.65	26.97	45.72
		.4	2782	1693	60.86	49.91	21.88	32.90
		.2	5755	2897	50.34	36.86	14.62	19.44
3e	Vertical Stiffness 120% of Nominal							
	Stabilized Landing	.6	1850	1227	66.32	55.57	26.70	43.33
		.4	2749	1693	61.59	51.45	21.73	33.28
		.2	5671	2897	51.08	37.88	15.22	19.08
	Wet Runway		5117	2996	58.55	40.63	18.58	19.55
3f	Vertical Stiffness 80% of Nominal							
	Stabilized Landing	.6	1869	1227	69.65	57.22	26.64	45.02
		.4	2760	1693	61.34	51.57	22.15	32.91
		.2	5661	2897	51.17	38.26	15.57	17.95
	Wet Runway		5102	2996	58.72	41.35	18.68	19.25
3g	Vertical Damping 120% of Nominal							
	Stabilized Landing	.6	1845	1227	66.50	56.67	26.14	46.04
		.4	2764	1693	61.25	51.42	21.97	33.11
		.2	5671	2897	51.08	38.14	15.49	18.25
	Wet Runway		5116	2996	58.63	41.00	18.62	19.44
	Mu Steps		5117			40.63	18.59	19.55
3h	Vertical Damping 80% of Nominal							
	Stabilized Landing	.6	1825	1227	67.23	57.86	27.89	42.20
		.4	2767	1693	61.19	50.97	21.83	33.56
		.2	5660	2897	51.18	38.25	15.52	18.08
	Wet Runway		5119	2996	58.53	40.78	18.54	19.88
	Mu Steps		5102			41.55	[illegible]	[illegible]
1a	Decrease Line Diameter 50%							
	Stabilized Landing	.6	1801	1227	68.13	54.77	26.85	44.91
		.4	3069	1693	56.16	42.33	22.83	34.11
		.2	[illegible]	2897	50.65	36.21	14.86	21.04
1b	Increase Line Diameter 50%							
	Stabilized Landing	.6	[illegible]	1227	[illegible]	[illegible]	[illegible]	45.02
		.4	[illegible]	[illegible]	[illegible]	[illegible]	22.49	[illegible]
		.2	[illegible]	[illegible]	[illegible]	35.50	14.25	26.55

Table 23.—C-141 Sensitivity Test Data (Concluded)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_e	η_D	SI	CI
1c	Move Dynamic Break Point Out 150% of Nominal							
	Stabilized Landing	.6	1761	1227	69.68	58.10	26.26	45.74
		.4	2710	1693	62.47	49.10	21.62	32.97
		.2	5533	2897	52.36	37.97	15.71	15.84
1d	Move Dynamic Break Point in 50% of Nominal							
	Stabilized Landing	.6	1819	1227	67.45	44.70	27.19	46.83
		.4	3144	1693	53.85	38.03	21.80	40.76
		.2	5815	2897	49.82	36.80	15.37	28.74
1e	Insert 20% Restriction in Return Line							
	Stabilized Landing	.6	1757	1227	69.85	58.27	25.67	46.25
		.4	2687	1693	63.01	49.91	21.33	35.07
		.2	5634	2897	51.42	37.07	15.04	20.33
	Mu Steps		2424			50.81	21.15	38.62
1f	Increase Brake Volume by 10 in^3							
	Stabilized Landing	.6	1822	1227	67.34	53.68	26.34	44.97
		.4	2698	1693	62.75	49.69	21.82	34.27
		.2	5654	2897	51.24	36.95	15.00	21.54
1g	Increase Brake p-V Gain							
	Stabilized Landing	.6	1740	1227	70.52	58.68	26.99	44.71
		.4	2624	1693	64.52	51.50	22.25	33.49
		.2	5344	2897	54.21	39.92	16.49	14.59

Table 24.—F-4 Baseline Braking Data

Condition	Mu	X_A	X_p	η_s	η_D	SI	CI
Test 2:							
Touchdown dynamics	0.6	2898	1876	64.73	51.59	5.03	70.78
	0.5	3371	2103	62.39	46.05	2.79	74.35
	0.4	4037	2415	59.82	39.74	1.50	77.00
	0.3	5473	2875	52.53	26.35	0.22	84.20
	0.2	8654	3645	42.12	18.12	0.06	90.31
	0.1*						
Test 3:							
Stabilized landing	0.6	2766	1876	67.82	51.11	4.88	73.45
	0.5	3273	2103	64.25	43.94	2.43	76.45
	0.4	3974	2415	60.77	38.62	1.04	79.12
	0.3	5261	2875	54.65	28.75	0.10	85.42
	0.2	8593	3645	42.42	18.38	0.07	90.04
	0.1**						
Test 4:							
Mu steps	0.1 to 0.5	3833	---	---	44.79	2.48	75.38
Test 5:							
Wet runway	0.05 to 0.5	5890	3766	63.94	29.91	0.12	84.13

* System would not operate

** System overloaded

Table 25.—F-4 Sensitivity Test Data

CONDITION	DESCRIPTION	MU	X_A	X_P	η_e	η_B	SI	GI
1a	Maximum Landing Weight							
	Stabilized Landing	.6	3255	2426	74.53	64.70	15.85	67.08
		.4	4880	3114	63.81	45.85	4.06	75.34
		.2	8852	4663	52.80	23.95	.06	87.15
	Wet Runway		7392	5184	65.69	33.68	.74	82.26
1b	Minimum Landing Weight							
	Stabilized Landing	.6	2704	1618	59.84	46.03	2.10	75.84
		.4	3841	2088	54.36	34.21	.29	81.55
		.2	8271	3175	38.39	19.40	.07	88.31
	Wet Runway		5394	3269	60.60	25.70	.01	86.45
2a	High Center of Gravity							
	Stabilized Landing	.6	TEST	NOT	RUN			
		.4						
		.2						
	Wet Runway							
2b	Low Center of Gravity							
	Stabilized Landing	.6	TEST	NOT	RUN			
		.4						
		.2						
	Wet Runway							
2c	Forward Center of Gravity							
	Stabilized Landing	.6	2904	1899	65.39	50.73	4.65	73.26
		.4	4144	2442	58.93	37.53	.82	80.36
		.2	8502	3683	43.32	18.18	.07	90.53
	Wet Runway		5860	3805	64.93	28.95	.05	84.80
2d	Aft Center of Gravity							
	Stabilized Landing	.6	2816	1863	66.16	51.19	4.92	73.26
		.4	4067	2400	59.01	37.27	.78	80.60
		.2	8851	3626	43.42	18.16	.07	90.29
	Wet Runway		5770	3760	65.16	28.92	.04	85.03
3a	Brakes on Speed + 10%							
	Stabilized Landing	.6	3370	2184	64.81	45.47	4.07	76.20
		.4	4566	2766	60.58	35.78	.71	81.37
		.2	8825	4061	46.02	18.96	.07	89.84
	Wet Runway		6359	4271	67.16	27.91	.02	85.52
3b	Brakes on Speed + 20%							
	Stabilized Landing	.6	3907	2497	63.91	41.87	3.49	78.20
		.4	5022	3115	62.08	34.70	.78	81.70
		.2	8885	4459	50.19	21.73	.07	88.40
	Wet Runway		6788	4731	69.70	28.73	.03	86.00
4a	Drag Device Deployment 1.0 Second After Touchdown							
	Stabilized Landing	.6	2479	1960	65.79	50.41	4.73	73.78
		.4	4185	2512	60.02	35.10	.92	80.00
		.2	8316	3762	45.22	21.51	.07	88.48
	Wet Runway		6004	4006	66.72	29.30	.04	84.65
	Touchdown Profile	.6	3134	1960	62.54	48.90	4.50	72.50
		.4	4335	2512	57.95	37.71	1.21	78.46
		.2	8740	3762	43.04	20.65	.10	87.95

Table 25.—F-4 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_e	η_B	SI	$\tilde{C}I$
4b	Drag Device Deployment 2.0 second after touchdown							
	Stabilized Landing	.6	3089	2086	65.91	50.14	4.76	73.79
		.4	4381	2607	59.91	37.20	.95	79.86
		.2	8726	3883	44.48	19.80	.07	89.49
	Wet Runway		6250	4126	66.02	28.09	.06	84.96
	Touchdown Profile	.6	3285	2036	62.02	48.08	4.34	73.77
		.4	4485	2607	58.13	37.22	1.26	78.83
		.2	8950	3863	45.47	20.60	.11	87.84
4c	No Spoilers/Drag Devices							
	Stabilized Landing	.6	4095	2378	58.07	51.63	5.81	73.48
		.4	7061	3244	45.94	34.74	1.26	81.63
		.2	COMPUTER	OVERLOAD				
	Wet Runway		13,185	6755	51.23	24.68	.28	87.11
4d	60% Effective Spoilers							
	Stabilized Landing	.6	3215	2058	64.01	52.04	5.04	73.57
		.4	4880	2701	55.69	37.39	1.14	79.94
		.2	10,738	4232	39.41	19.47	.06	89.13
	Wet Runway		7670	4611	60.12	26.28	.08	86.17
4e	40% Effective Spoilers							
	Stabilized Landing	.6	3427	2143	62.53	51.79	5.51	73.36
		.4	5326	2841	53.34	36.47	1.08	81.02
		.2	12,274	4535	36.95	18.45	.06	91.93
	Wet Runway		8690	5061	58.24	28.65	.08	86.61
4f	120% Engine Idle Thrust							
	Stabilized Landing	.6	2893	1917	66.26	52.88	5.00	72.95
		.4	4196	2484	59.20	38.84	1.04	79.27
		.2	10,615	3814	35.93	18.96	.05	91.69
	Wet Runway		6338	3943	62.21	27.54	.06	88.43
4g	80% Engine Idle Thrust							
	Stabilized Landing	.6	2722	1834	67.38	51.45	4.65	73.84
		.4	3836	2347	61.18	38.20	.91	79.69
		.2	7218	3488	48.32	19.03	.02	88.66
	Wet Runway		5451	3613	66.28	27.52	.03	85.42
5a	150% Nominal Pressure Application Rate							
	Stabilized Landing	.6	2758	1876	68.02	53.69	4.93	72.66
		.4	3916	2419	60.74	39.35	1.03	79.00
		.2	8401	3645	43.39	19.29	.07	89.43
	Wet Runway		5895	3766	63.88	27.50	.05	86.89
	Touchdown Profile	.6	2911	1876	64.44	51.47	4.81	71.62
		.4	4097	2419	58.95	38.92	1.36	77.52
		.2	Wheels	Locked	Up, Would	Not	Run	

Table 25.–F-4 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_a	η_b	OI	OI
5b	50% Nominal Pressure Application Rate							
	Stabilized Landing	.6	2798	1876	67.95	32.01	4.78	72.90
		.4	3988	2415	60.56	38.97	1.06	79.37
		.2	8603	3645	42.37	17.72	.07	90.53
	Wet Runway		5926	3766	63.55	26.23	.03	86.11
	Touchdown Profile	.6	2974	1876	63.08	49.26	4.37	73.12
		.4	4128	2415	58.50	38.38	1.17	78.55
		.2	8865	3645	41.11	18.41	.07	89.42
5c	Nominal Rate at 2.0 seconds From Touchdown							
	Stabilized Landing	.6	2437	1579	64.79	48.65	4.29	75.08
		.4	3533	2068	58.53	38.35	1.00	79.75
		.2	8108	3218	39.69	17.98	.07	89.63
	Wet Runway		5440	3299	60.64	25.35	.02	86.55
	Touchdown Profile	.6	2502	1579	63.11	47.95	4.60	73.46
		.4	3640	2068	56.81	37.81	1.25	79.06
		.2	8382	3218	38.39	18.14	.07	88.81
5d	Nominal Rate at 4.0 Seconds From Touchdown							
	Stabilized Landing	.6	2087	1378	66.08	45.57	4.03	76.93
		.4	3155	1827	57.90	36.95	.87	80.56
		.2	7436	2910	39.13	18.57	.06	89.66
	Wet Runway		5025	2859	56.90	24.57	.02	87.04
	Touchdown Profile	.6	2166	1378	63.65	45.31	4.26	75.21
		.4	3254	1827	56.15	36.70	1.18	79.60
		.2	7877	2910	36.94	18.21	.06	88.97
5e	75% Of Full Metered Pressure							
	Stabilized Landing	.6	2357	1816	79.59	68.75	9.94	63.53
		.4	3580	2415	68.05	49.26	2.39	72.92
		.2	6854	3645	53.18	25.50	.02	84.66
	Wet Runway		5532	3766	68.08	31.35	.19	82.73
5f	50% Of Full Metered Pressure							
	Stabilized Landing	.6	2229	1876	84.16	73.13	10.90	63.53
		.4	3027	2415	79.78	66.81	4.81	65.00
		.2	5997	3645	60.84	33.85	.24	76.81
	Wet Runway		5236	3766	11.93	33.80	.29	82.08
1a	10 Knot Wind							
	Stabilized Landing	.6	2355	1632	69.30	53.40	4.48	12.06
		.4	3342	2089	62.51	38.85	.73	[illegible]
		.2	6564	3107	48.82	18.22	.02	89.38
	Wet Runway		4707	3082	65.48	27.07	.01	85.62
1b	20 Knot Wind							
	Stabilized Landing	.6	1961	1388	70.78	54.73	3.97	71.56
		.4	2767	1764	63.75	34.62	.51	79.00
		.2	4875	2569	52.69	17.49	.01	90.26
	Wet Runway		5746	2508	66.95	27.39	.00	85.24

Table 25.—F-4 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_a	η_b	[illegible]	[illegible]
1c	-10 Knot Wind							
	Stabilized Landing	.6	3339	2119	63.46	50.14	5.16	73.63
		.4	4745	2740	57.74	38.34	1.30	79.66
		.2	11014	4183	37.98	19.95	.06	90.12
	Wet Runway		7416	4546	61.30	27.25	.10	85.67
2a	Hot Day - High Altitude							
	Stabilized Landing	.6	2946	1952	66.26	54.36	5.79	72.05
		.4	43[illegible]0	2557	58.25	40.05	1.25	79.01
		.2	9811	3985	40.62	19.27	.06	89.90
	Wet Runway		7002	4274	61.04	26.73	.05	86.96
2b	Cold Day - Sea Level							
	Stabilized Landing	.6	2600	1776	68.31	49.61	3.74	74.07
		.4	3480	2288	64.31	39.04	.78	79.22
		.2	6950	3258	46.88	19.01	.06	88.44
	Wet Runway		4850	3257	67.15	27.86	.02	88.29
3a	Rough Surface Runway							
	Stabilized Landing	.6	2789	1876	67.26	52.29	5.01	73.07
		.4	3968	2415	60.86	39.57	1.19	79.08
		.2	8457	3645	42.60	18.88	.07	90.00
	Wet Runway		5708	3766	63.74	27.11	.03	85.52
1a	High Fade Brake							
	Stabilized Landing	.6	2787	1876	67.31	5261	4.72	72.65
		.5	3321	2103	63.32	45.18	2.48	75.20
		.4	3976	2415	60.74	39.40	.99	79.18
1b	Low Fade Brake							
	Stabilized Landing	.6	2777	1876	67.95	52.95	4.80	72.24
		.5	3311	2103	63.52	46.48	2.49	76.25
		.4	3965	2415	60.91	39.70	1.00	79.15
1c	Torque Peaking to 150% of Running							
	Stabilized Landing	.6	2733	1876	68.64	54.00	5.15	71.23
		.4	3931	2415	61.43	40.20	1.03	78.76
		.2	8569	3645	42.54	18.45	.06	90.25
	Wet Runway		5878	3766	64.07	27.33	.02	85.58
1d	No Torque Peaking							
	Stabilized Landing	.6	2788	1876	67.29	52.49	4.83	73.14
		.4	3963	2415	60.94	40.22	1.02	78.86
		.2	8388	3645	43.45	19.21	.06	89.89
	Wet Runway		5906	3766	63.77	27.21	.03	85.70
1e	Torque Response Break Point 150% Nominal							
	Stabilized Landing	.6	2646	1876	70.90	57.46	5.48	69.89
		.4	3892	2415	62.05	40.87	1.01	78.35
		.2	8522	3645	43.54	18.45	.06	90.26
1f	Torque Response Break Point 50% Nominal							
	Stabilized Landing	.6	2872	1876	65.32	49.94	4.11	74.26
		.4	4061	2415	59.47	38.04	.84	79.65
		.2	8646	3645	42.16	17.76	.06	90.49

Table 25.--F-4 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_s	η_p	[illegible]	[illegible]
1g	Torque Gain 120% of Nominal							
	Stabilized Landing	.6	3201	1876	58.61	39.57	2.82	79.17
		.4	4461	2415	54.14	29.92	.45	83.60
		.2	8977	3645	40.60	16.38	.06	91.42
	Wet Runway		6415	3766	58.71	20.98	.01	88.80
1h	Torque Gain 80% of Nominal							
	Stabilized Landing	.6	2373	1867	79.06	68.67	9.42	64.78
		.4	3594	2415	67.20	48.57	2.21	72.27
		.2	7314	3645	49.84	22.85	.02	87.76
	Wet Runway		5502	3766	68.45	32.96	.19	82.19
1i	Variable Torque Gain T = F (p)[5]							
	Stabilized Landing	.6	2336	1876	80.31	70.67	9.56	64.10
		.4	4061	2415	59.47	40.69	1.47	77.63
		.2	7826	3645	46.58	28.15	.35	81.88
	Wet Runway		5942	3766	63.38	36.75	.56	79.14
1j	Linear Torque Gain T = F(p)							
	Stabilized Landing	.6	2745	1867	68.34	52.50	4.94	73.21
		.4	37[illegible]	2415	64.68	44.06	1.60	75.52
		.2	6668	3645	54.66	25.68	.01	86.80
	Wet Runway		5448	3766	69.13	31.22	.13	82.94
2a	Tire Inflation Pressure 120% of Nominal							
	Stabilized Landing	.6	2383	1876	78.72	65.48	6.13	78.74
		.4	3406	2415	70.90	51.23	1.55	83.08
		.2	9226	3645	39.51	15.34	.06	96.10
2b	Tire Inflation Pressure 80% of Nominal							
	Stabilized Landing	.6	3510	1876	53.45	33.99	2.81	73.80
		.4	4673	2415	51.68	27.17	.52	79.09
		.2	8551	3645	42.63	15.72	.07	87.80
2c	50% Worn Tire							
	Stabilized Landing	.6	2971	1876	63.14	46.57	3.64	76.08
		.4	4172	2415	57.89	34.90	.64	81.46
		.2	9112	3645	40.00	15.91	.06	91.99
	Wet Runway		6100	3766	61.74	24.11	.01	87.36
2d	80% Worn Tire							
	Stabilized Landing	.6	3136	1876	59.82	42.44	2.70	78.12
		.4	4314	2415	55.98	32.91	.50	82.35
		.2	9145	3645	39.86	17.69	.06	90.97
	Wet Runway		6178	3766	60.95	23.52	.01	87.50
2e	Low Tire Heating							
	Stabilized Landing	.6	2775	1876	67.60	52.28	5.16	72.15
		.4	3971	2415	60.82	39.15	1.00	79.24
		.2	7822	3645	46.60	18.70	.05	89.88
	Wet Runway		5811	3766	64.81	27.25	.02	85.52
2f	Flat μ-σ Peak							
	Stabilized Landing	.6	[illegible]	1876	67.95	53.10	[illegible]	11.23
		.4	[illegible]	2415	60.91	[illegible]	1.06	78.97
		.2	[illegible]	3645	48.02	19.28	.01	89.64
	Wet Runway		[illegible]	3766	65.23	[illegible]	.04	84.97

Table 25.—F-4 Sensitivity Test Data (Continued)

CONDITION	DESCRIPTION	MU	X_A	X_P	η_S	η_D	SI	CI
3a	Maximum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	2745	1876	68.34	58.39	6.00	72.44
		.4	3961	2415	60.97	39.13	.99	79.67
		.2	8631	3645	42.23	17.48	.06	90.73
3b	Minimum Strut Frequency Varying The Mass							
	Stabilized Landing	.6	2740	1876	68.47	54.29	5.53	72.28
		.4	4067	2415	59.38	37.10	.98	79.89
		.2	8346	3645	43.67	18.87	.07	89.88
3c	Maximum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	2820	1876	66.52	51.47	4.87	73.00
		.4	3992	2415	60.50	39.06	.95	79.53
		.2	8432	3645	43.23	18.31	.06	90.23
3d	Minimum Strut Frequency Varying The Stiffness							
	Stabilized Landing	.6	2798	1876	67.05	52.12	5.05	72.69
		.4	4139	2415	58.55	56.71	.65	81.19
		.2	8613	3645	42.32	17.56	.06	90.65
3e	Vertical Stiffness 120% of Nominal							
	Stabilized Landing	.6	2810	1876	66.76	51.67	4.41	73.52
		.4	4005	2415	60.30	38.30	.89	79.68
		.2	8515	3645		17.78	.06	89.34
	Wet Runway		5945	3766	63.34	26.35	.02	86.93
3f	Vertical Stiffness 80% of Nominal							
	Stabilized Landing	.6	2790	1876	67.24	52.00	4.69	72.86
		.4	3985	2415	60.60	38.65	.95	79.73
		.2	8677	3645	42.25	17.65	.06	90.68
	Wet Runway		5959	3766	63.20	25.90	.01	86.60
3g	Vertical Damping 120% of Nominal							
	Stabilized Landing	.6	2781	1876	67.46	52.43	4.71	73.07
		.4	3986	2415	60.59	38.62	.94	79.79
		.2	8647	3645	41.91	17.27	.06	89.22
	Wet Runway		5948	3766	63.32	26.05	.01	86.39
	Mu Steps		3486			44.66	2.62	73.89
3h	Vertical Damping 80% of Nominal							
	Stabilized Landing	.6	2778	1876	67.53	52.32	4.76	73.25
		.4	3982	2415	60.65	38.57	.98	79.97
		.2	8630	3645	42.24	17.63	.06	89.67
	Wet Runway		5945	3766	63.34	25.85	.02	86.55
	Mu Steps		3433			45.89	2.67	73.60
1a	Decrease Line Diameter 50%							
	Stabilized Landing	.6	TEST NOT RUN					
		.4						
		.2						
1b	Increase Line Diameter 50%							
	Stabilized Landing	.6	7367	1876	79.26	64.14	8.59	67.38
		.4	3608	2415	66.93	42.20	1.80	77.94
		.2	7756	3645	47.00	17.65	.07	92.58

Table 25.—F-4 Sensitivity Test Data (Concluded)

CONDITION	DESCRIPTION	MU	X_A	X_P	$\dot{\eta}$	η_B	SI	CI
1c	Move Dynamic Break Point Out 150% of Nominal							
	Stabilized Landing	.6	2697	1876	69.56	51.51	4.75	73.67
		.4	4027	2415	59.97	30.37	.51	83.25
		.2	11030	3645	33.05	4.14	.05	100.00
1d	Move Dynamic Break Point in 50% of Nominal							
	Stabilized Landing	.6	2761	1876	67.95	53.89	5.10	72.61
		.4	3922	2415	61.68	41.38	1.20	77.78
		.2	7606	3645	47.92	23.08	.05	86.32
1e	Insert 20% Restriction in Return Line							
	Stabilized Landing	.6	2746	1876	68.82	53.08	4.98	72.55
		.4	3922	2415	61.58	39.29	1.00	79.84
		.2	8538	3645	42.69	16.81	.06	91.08
	Mu Steps		3456			44.72	2.48	74.21
1f	Increase Brake Volume by 10 in^3							
	Stabilized Landing	.6	2615	1876	71.74	57.38	5.99	70.98
		.4	3803	2415	63.50	41.51	1.29	78.25
		.2	8148	3645	44.75	17.40	.06	90.63
1g	Increase Brake psv Gain							
	Stabilized Landing	.6	4237	1876	44.28	23.29	.86	87.48
		.4	5252	2415	45.98	21.87	.29	88.55
		.2	8605	3645	42.37	20.18	1.12	78.48

SECTION XI

STABILITY TEST RESULTS

1. STRUT RESPONSE DAMPING

In addition to the performance studies, stability studies were conducted to evaluate the tendency of a skid control system to contribute to the stability of the landing gear. These tests were designed to measure system ability to provide damping to the strut motion or, conversely, its tendency to couple in the oscillation, thereby causing divergence.

The fore-aft damping in the landing gear model was varied until the point of divergent gear oscillation was reached. The damping ratio was then determined at this point. By comparing the damping ratio of the baseline airplane to the damping ratio resulting from a parameter change, a qualitative statement may be made about the effect such a change would have on gear stability and stopping performance.

The damping ratio is a measure of how fast strut oscillations are attenuated. To determine the damping ratio a step torque input was made to the strut model. The resulting strut displacement was monitored as a function of time. The damping ratio was then calculated from:

$$\xi = \frac{\ln\left[\dfrac{A_o}{A(t)}\right]}{2\pi n}$$

where:

ξ = damping ratio

n = number of full strut oscillations

A_o = strut amplitude at time zero

$A(t)$ = strut amplitude after n strut oscillations.

The damping ratios and the related test conditions are listed in Table 26 for each aircraft.

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Table 26.—Stability Test Results (Test 1)

Test no.	Condition	Damping Ratio 727	737	747	C-141	F-4
	Baseline ξ	2.03	3.03	5.6	4.1	1.58
5a	150% nominal pressure application rate	Stable	Stable	Stable	Test not run	Test not run
5b	50% nominal pressure application rate					
5c	Nominal rate at 20 sec from touchdown				Test not run	Test not run
1c	Torque peaking				Stable	Stable
1d	No torque peaking					
1e	Torque response breakpoint 150% of nominal					
1f	Torque response breakpoint 50% of nominal					
1g	Torque gain 120% of nominal					
1h	Torque gain 80% of nominal					
1i	Variable torque gain $T = F(p)^{0.5}$					
2a	Inflation pressure 120% of nominal					
2b	Inflation pressure 80% of nominal	Stable	Stable	Stable	Stable	Stable
3a	Maximum strut frequency varying mass	7.6	5.13	5.34	6.6	1.36
3b	Minimum strut frequency varying mass	6.5	0.47	5.70	2.8	1.10
3c	Maximum strut frequency varying stiffness	4.6	4.55	2.30	5.0	1.39
3d	Minimum strut frequency varying stiffness	12.3	0.57	Test not run	3.5	1.99
a	Decrease line diameter 50%	Stable	Stable	Test not run	Stable	Test not run
b	Increase line diameter 50%			Stable		Stable
c	Move dynamic breakpoint out 150% of nominal	Stable	Stable	Stable	Stable	Stable

Table 26.—Stability Test Results (Test 1) (Concluded)

Test no.	Condition	Damping ratio				
		727	737	747	C-141	F-4
d	Move dynamic breakpoint to 50% of nominal	Stable	Stable	Stable	Stable	Stable
e	Insert 20% restriction in return line					
f	Increase brake volume by 10 cu in.			Stable		
g	Increase brake p - v gain	Stable	Stable	Unstable hydraulic configuration	Stable	Stable

2. MU-SLIP CURVE SHAPE VARIATIONS

An important aspect of the landing gear model was the simulation of tire-runway friction. For the sensitivity studies, the coefficient of ground friction was taken to be a function of the percentage of tire slippage. The actual mu-slip curve used for the baseline condition is well documented throughout the aircraft industry and is the result of numerous test programs. These tests have pointed out that various tire and runway parameters have an effect on the actual shape of the mu-slip curve. In addition, each skid control system has a significant impact on the shape because of their difference in thermal management. This affects both the peak mu and slope of the back side of the mu-slip curve. The relationship between ground friction and tire slippage was changed and braking performance recorded to evaluate the consequence of different mu-slip curves. The mu-slip curves used in these sensitivity tests are depicted in Figure B-5, ASD-TR-74-41, Volume I, Appendix B, along with the baseline curve.

The braking performance resulting from these tests is random. The randomness resulted from the difference in operational characteristics of each antiskid system. Thus, to adequately analyze the braking performance results, each airplane must be considered individually. The following paragraphs explain how each antiskid system reacted to the changed mu-slip curve, thus producing the recorded braking performance. The regions over which each antiskid system operates, as defined in Section VIII, help to explain the performance. Each system operated over the same range of slip ragardless of the curve shape.

a. TIRE INFLATION PRESSURE 120% OF NOMINAL (Test 2a)

This change has the effect of lowering the percentage of available mu for values of slip greater than 6%. On surfaces that exhibit reasonable mu the Boeing 727, 737, and 747 and the C-141 operated predominately at slip values greater than 6%. Thus, the lower friction coefficient at the tire-runway interface resulted in longer stopping distances. The F-4, however, operated on the front side of the curve where the percentage of available mu has increased, permitting shorter braking distances. When the F-4 antiskid system cycles over the peak, as was the case when the peak available mu was lowered to 0.2, the percentage of available mu was decreased, and the braking distance was increased.

b. TIRE INFLATION PRESSURE 80% OF NOMINAL (Test 2b)

The 80% inflation pressure change raised the percen[illegible] of available mu for slip values greater than 15% and decreased the percentage of available mu when slip was less than 15%. For the antiskid systems that cycled near the peak and on the back side, braking distance was shorter as a result of the increase in the percentage of available mu. The F-4, which operated on the front side of the curve at high mu values exhibited increased braking distances resulting from lower available mu.

c. **LOW TIRE HEATING AND FLAT MU-SLIP PEAK** (Tests 2e and 2f)

These two tests raised the percentage of available mu for slip values greater than 10%. The front side slope and peak mu location were unchanged. The results showed that, for systems operating at the peak or on the back side of the curve, braking distances decreased. In addition, the higher the back side mu, the shorter the distance. Since the front of the mu-slip curve is unchanged, the F-4 did not show a significant variation from the baseline braking distance.

SECTION XII

PARAMETER RATINGS

The following tables present the baseline braking distance percentages for frictional values of 0.6, 0.4, and 0.2. Also shown is the parameter rating index (PRI) for all test conditions. Table 27 summarizes the percentages for all aircraft studied and lists the composite PRI. Tables 28 through 32 contain individual PRI values for the 727, 737, 747, C141, and F-4.

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Table 27.—Summary of Parameter Ratings

Condition Description	Baseline brake distance (dry—stabilized landings)															PRI
	Mu = 0.6					Mu = 0.4					Mu = 0.2					
	727	737	747	F-14	F-4	727	737	747	F-14	F-4	727	737	747	F-14	F-4	
1a Maximum Landing Weight	110	131	110	117	118	110	129	110	115	123	109	127	110	115	105	13.5
1b Minimum Landing Weight	88	90	80	90	90	87	90	91	90	97	101	91	88	81	96	11.6
2a High Center of Gravity		101					101					101				1.0
2b Low Center of Gravity		100					100					101				.5
2c Forward Center of Gravity	108	108	105	106	106	105	104	108	106	104	108	108	105	105	99	4.1
2d Aft Center of Gravity	97	96	97	98	102	96	96	98	98	102	98	97	98	98	97	2.6
3a Brakes on Speed + 10%	115	119	111	117	122	114	118	111	115	115	120	116	110	111	103	14.5
3b Brakes on Speed + 20%	132	137	125	139	141	132	136	127	130	126	132	132	119	121	103	27.9
4a Drag Device Deployment @ 1 sec	112	113	109	108	108	108	108	109	106	105	113	109	109	104	97	7.9
4b Drag Device Deployment @ 2 sec	121	120	114	115	112	114	114	111	110	110	117	108	107	106	102	12.0
4c No Spoilers/Drag Device	180	157	132	160	148	205	142	153	166	178	179		136	●	●	66.2
4d 60% Effective Spoilers	112	115	109	116	116	116	114	111	117	122	131	118	112	119	128	16.5
4e 40% Effective Spoilers	122	125	118	127	124	136	128	117	130	134	143	127	119	125	143	27.5
4f 120% Engine Idle Thrust	102	100	101	101	105	101	100	101	102	106	119	102	102	103	124	4.5
4g 80% Engine Idle Thrust	100	100	98	99	98	99	99	98	98	96	97	99	96	96	84	2.9
5a 120% Nom. Press. Appl. Rate	99	98	98		100	98	99	99		100	104	100	99		98	1.1
5b 50% Nom. Press. Appl. Rate	102	101	100		101	100	100	100		100	101	100	100		100	.4
5c Nom. Rate at 2 sec. after TD	122	126	119		106	115	118	116		101	114	128	107		100	13.6
5d Nom. Rate at 4 sec. after TD	148	148	136		109	130	155	128		103	116	130	106		97	23.8
5e 75% of Full Metered Pressure	106	101	99	96	88	106	106	100	102	89	106	106	99	104	80	5.2
5f 50% of Full Metered Pressure	128	116	117	77	80	104	104	102	84	76	119	105	99	109	70	15.5
1a 10 Knot Wind	83	81	92	85	85	82	81	91	85	84	80	80	89	80	14	16.7
1b 20 Knot Wind	68	64	66	71	71	67	64	65	65	70	64	62	65	62	57	30.6
1c -10 Knot Wind	118	119	108	117	121	117	120	108	116	119	123	122	110	120	118	17.7
2a Hot Day	102	101	98	104	107	102	102	99	103	110	109	108	101	108	114	4.8
2b Cold Day	97	97	103	99	94	94	96	102	98	87	91	94	97	91	81	6.1
3a Rough Surface Runway	100	104	102	102	101	100	102	102	100	100	100	100	101	101	100	1.1
1a High Fade Brake	99	98	99	109	101	99	99	100	99	100						.8
1b Low Fade Brake	100	98	99	100	100	99	99	100	100	100						.3
1c Torque Peaking 150% of Running	101	99	[illegible]	99	99	99	100	101	99	97	98	100	100	100	100	.7
1d No Torque Peaking	100	98	99	109	101	99	99	98	99	100	99	99	100	100	98	.9
1e Torque Response BP 150% of Nom.	100	97	98	101	96	98	98	98	99	98	100	100	97	98	97	1.8
1f Torque Response BP 50% of Nom.	101	102	100	108	104	99	102	102	103	102	98	101	104	101	101	1.9
1g Torque Gain 120% of Nominal	101	112	101	106	116	108	99	103	112	112	120	100	105	102	104	6.7
1h Torque Gain 80% of Nominal	108	98	99	102	86	98	100	100	98	90	89	101	99	98	98	5.5
1i Variable Torque Gain $T=f(p)^2$	103	100	99	96	84	98	100	101	103	102	86	100	102	102	91	4.5
1j Linear Torque Gain $T=f(p)$	102	99	100	106	99	101	99	99	101	94	74	100	98	92	77	2.9
2a Tire Infl. Press. 120% of Nom.	101	112	103	105	86	104	112	106	108	86	129	109	107	110	107	9.8
2b Tire Infl. Press. 80% of Nom.	102	98	100	95	121	100	95	97	93	118	89	97	98	86	100	6.8
2c 50% Worn Tire	101	99	100	100	107	100	99	101	101	105	101	109	102	101	106	1.8
2d 80% Worn Tire	103	100	100	102	113	104	100	101	101	109	110	100	102	102	106	5.5
2e Low Tire Heating	99	95	95	91	109	97	94	95	85	100	15	96	96	73	91	8.0
2f Flat μ-φ Peak	96	91	94	88	100	96	92	94	82	100	72	94	98	70	88	9.9
3a Max. Strut Freq. Varying Mass	100	99	100	102	99	100	99	101	101	100	104	100	102	102	100	1.0
3b Min. Strut Freq. Varying Mass	108	98	100	101	99	100	99	101	102	102	104	100	101	102	97	1.9
3c Max. Strut Freq. Var. Stiffness	96	99	100	103	102	100	99	100	101	100	94	100	99	102	98	1.4
3d Min. Strut Freq. Var. Stiffness	109	99		109	101	101	99		101	104	103	100		102	100	2.0
3e Vert. Stiffness 120% of Nominal	101	100	99	100	102	100	99	100	100	101	99	100	99	100	99	.6
3f Vert. Stiffness 80% of Nominal	100	99	99	102	101	100	100	99	100	100	102	100	99	100	100	.6
3g Vert. Damping 120% of Nominal	100	100	99	100	101	100	100	99	100	100	103	100	99	100	101	.4
3h Vert. Damping 80% of Nominal	100	99	99	99	100	100	100	100	100	100	101	100	99	100	100	.5
1a Decrease Line Diameter 50%	100	103		98		102	103		114		102	101		101		2.9
1b Increase Line Diameter 50%	102	103	98	99	88	103	103	99	114	91	107	102	99	103	90	5.1
1c Dynamic BP 150% of Nominal	100	98	98	96	98	98	99	99	98	128	101	101	98	98	128	5.2
1d Dynamic BP 50% of Nominal	99	108	100	109	100	101	103	101	123	89	112	103	102	102	88	5.4
1e 20% Restriction in Return Line	99	100	101	95	99	100	101	102	97	99	98	101	106	100	99	1.7
1f Increase Brake Vol. by 10 in^3	99	102	99	99	94	100	102	100	98	96	106	101	102	100	95	2.2
1g Increase Brake p-v Gain	106	96		94	188	98	103		95	132	104	100		94	100	10.1

Notes: 1. Blanks indicate that the test was not performed. 2. ● = Distance greater than computer's capacity.

Table 28.—727 Parameter Ratings

Rank	Test condition	Description	Parameter rating index
1	4c	No spoilers or drag devices	87.33
2	1b	20 knot wind	33.67
	4c	40% effective spoilers	33.67
4	3b	Brake application speed + 20%	32.00
5	5d	Nominal pressure rate at 4.0 sec	31.00
6	4d	60% effective spoilers	19.67
7	1c	-10 knot wind	19.33
8	1a	10 knot wind	18.33
9	4b	Spoiler deployment at 2.0 sec	17.33
10	5c	Nominal pressure rate at 2.0 sec	17.00
11	3a	Brake application speed – 10%	16.33
12	5f	50% of full metered pressure	16.00
13	2f	Flat mu-slip peak	12.00
14	4a	Spoiler deployment at 1.0 sec	11.67
15	2a	Tire inflation pressure 120% of nominal	11.33
16	1b	Minimum landing weight	10.67
17	1a	Maximum landing weight	9.67
	1j	Linear torque gain	9.67
	2e	Low tire heating	9.67
20	1g	Torque gain 120% of nominal	8.66
21	1i	Variable torque gain	8.33
22	1h	Torque gain 80% of nominal	7.00
23	2b	Cold day	6.00
	5e	75% of full metered pressure	6.00
25	4f	120% engine idle thrust	5.33
	2d	80% worn tire	5.33
27	d	Move dynamic breakpoint in 50% of nominal . . .	4.67
28	2a	Hot day	4.33
	2b	Tire inflation pressure 80% of nominal	4.33
	2c	Forward center of gravity	4.33
	3d	Minimum strut frequency varying stiffener	4.33
32	3b	Minimum strut frequency varying mass	4.00
	b	Increase line diameter 50%	4.00
	g	Increase brake p - v gain	4.00

Table 28.—727 Parameter Ratings (Concluded)

Rank	Test condition	Description	Parameter rating index
35	2d	Aft center of gravity	3.00
36	3c	Maximum strut frequency varying stiffness	2.67
37	5a	150% nominal pressure application rate	2.33
	f	Increase brake volume by 10 cu in.	2.33
39	4g	80% engine idle thrust	1.33
	1c	Torque peaking 150% or running	1.33
	1f	Torque response breakpoint 50% of nominal	1.33
	3a	Maximum strut frequency varying mass	1.33
	a	Decrease line diameter 50%	1.33
44	c	Move dynamic breakpoint out 150% of nominal . . .	1.00
	e	Insert 20% restriction in return line	1.00
	1q	High-fade brake	1.00
	5b	50% nominal pressure application rate	1.00
48	1d	No torque peaking	0.67
	1c	Torque response breakpoint 150% of nominal	0.67
	2c	50% worn tire	0.67
	3c	Vertical stiffness 120% of nominal	0.67
	3f	Vertical stiffness 80% of nominal	0.67
	3g	Vertical damping 120% of nominal	0.67
54	1b	Low fade brake	0.50
55	3h	Vertical damping 80% of nominal	0.33
56	3a	Rough runway surface	0

Table 29.—737 Parameter Ratings

Rank	Test condition	Description	Parameter rating index
1	4c	No spoilers or drag devices	39.50
2	1b	20 knot wind	36.69
	5d	Nominal pressure rate at 4.0 sec	36.67
4	3b	Brake application speed + 20%	35.00
5	1a	Maximum landing weight	29.00
6	4e	40% effecting spoilers	25.00
7	5c	Nominal pressure rate at 2.0 sec	22.33
8	1c	-10 knot wind	20.33
9	1a	10 knot wind	19.33
10	3a	Brake application speed + 10%	17.67
11	4d	60% effecting spoiler	14.00
	4b	Spoiler deployment at 2.0 sec	14.00
13	2a	Tire inflation pressure 120% of nominal	11.00
14	1b	Minimum landing weight	9.67
15	4a	Spoiler deployment at 1.0 sec	8.67
16	5f	50% of full metered pressure	7.67
	2f	Flat mu-slip peak	7.67
18	2e	Low tire heating	5.67
19	2c	Forward center of gravity	4.67
20	2b	Cold day	4.33
	1g	Torque gain 120% of nominal	4.33
	2b	Tire inflation pressure 80% of nominal	4.33
23	d	Move dynamic breakpoint in 50% of nominal	3.67
24	2d	Aft center of gravity	3.67
25	b	Increase line diameter 50%	2.67
	2a	Hot day	2.67
27	a	Decrease line diameter 50%	2.33
	g	Increase brake p-v gain	2.33
	3a	Rough runway surface	2.33
30	1h	Torque gain 50% of nominal	2.00
	1f	Torque response breakpoint 50% of nominal	1.67
	1e	Torque response breakpoint 150% of nominal	1.67
	f	Increase brake volume by 10 cu in.	1.67

Table 29.—737 Parameter Ratings (Concluded)

Rank	Test condition	Description	Parameter rating index
34	1a	High fade brake	1.50
	1b	Low fade brake	1.50
36	c	Move dynamic breakpoint out 150% of nominal . . .	1.33
	1d	No torque peaking	1.33
38	2a	High center of gravity	1.00
	5a	150% nominal pressure application rate	1.00
	3b	Minimum strut frequency varying mass	1.00
41	4f	120% engine idle thrust	0.67
	4g	80% engine idle thrust	0.67
	1j	Linear torque gain	0.67
	2c	50% worn tire	0.67
	3a	Maximum strut frequency varying mass	0.67
	3c	Maximum strut frequency varying stiffness	0.67
	3d	Minimum strut frequency varying stiffness	0.67
	e	Insert 20% restriction in return line	0.67
43	2b	Low center of gravity	0.33
	5b	50% nominal pressure application rate	0.33
	5e	75% of full metered pressure	0.33
	1c	Torque peaking 150% of running	0.33
	3e	Vertical stiffness 120% of nominal	0.33
	3f	Vertical stiffness 80% of nominal	0.33
	3h	Vertical damping 80% of nominal	0.33
56	1i	Variable torque gain	0
	2o	80% worn tire	0
	3q	Vertical damping 120% of nominal	0

Table 30.—747 Parameter Ratings

Rank	Test condition	Description	Parameter rating index
1	4c	No spoiler or drag devices	33.67
2	5d	Nominal pressure rate at 4.0 sec	22.33
3	3b	Brake application speed + 20%	21.33
4	1b	Minimum landing weight	19.00
5	4e	40% effective spoilers	17.00
6	1b	20 knot wind	15.33
7	5c	Nominal pressure rate at 2.0 sec	13.00
8	3a	Brake application speed + 10%	10.67
	4b	Spoiler deployment at 2.0 sec	10.67
	4c	60% effective spoilers	10.67
11	1a	Maximum landing weight	10.00
12	1a	10 knot wind	9.33
13	1c	-10 knot wind	8.67
14	4a	Spoiler deployment at 1.0 sec	7.67
	5f	50% of full metered pressure	6.67
	2f	Flat mu-slip peak	5.67
	2q	Tire inflation pressure 120% of nominal	5.33
18	2c	Low tire heating	4.67
19	1q	Torque gain 120% of nominal	3.00
	e	Insert 20% restriction in return line	3.00
	2c	Forward center of gravity	3.00
22	4q	80% engine idle thrust	2.67
	2b	Cold day	2.67
24	2	Aft center of gravity	2.33
	1e	Torque response breakpoint 150% of nominal	2.33
26	1f	Torque response breakpoint 50% of nominal	2.00
27	2a	Hot day	1.67
	3a	Rough runway surface	1.67
	2b	Tire inflation pressure 80% of nominal	1.67
	c	Move dynamic breakpoint out 150% of nominal	1.67
31	4f	120% engine idle thrust	1.33
	5a	150% nominal pressure application rate	1.33
	1i	Variable torque gain	1.33
	b	Increase line diameter by 50%	1.33

Table 30.—747 Parameter Ratings (Concluded)

Rank	Test condition	Description	Parameter rating index
35	1d	No torque peaking	1.00
	1j	Linear torque gain	1.00
	2c	50% worn tire	1.00
	2d	80% worn tire	1.00
	3a	Maximum strut frequency varying mass	1.00
	3f	Vertical stiffness 80% of nominal	1.00
	3q	Vertical damping 120% of nominal	1.00
	d	Move dynamic breakpoint in 50% of nominal	1.00
	f	Increase brake volume by 10 cu in.	1.00
44	5e	75% of full metered pressure	0.67
	1h	Torque gain 80% of nominal	0.67
	3b	Minimum strut frequency varying mass	0.67
	3c	Vertical stiffness 120% of nominal	0.67
	3h	Vertical damping 80% of nominal	0.67
49	1a	High fade brake	0.50
	1b	Low fade brake	0.50
51	1c	Torque peaking 150% of running	0.33
	3c	Maximum strut frequency varying stiffness	0.33
53	5b	50% nominal pressure application rate	0

Table 31.—C-141 Parameter Ratings

Rank	Test condition	Description	Parameter rating index
1	4c	No spoilers or drag devices	63.00
2	1b	20 knot wind	33.00
3	3b	Brake application speed + 20%	28.33
4	4e	40% effective spoilers	27.33
5	2f	Flat mu-slip peak	20.00
6	1c	-10 knot wind	17.67
7	1a	10 knot wind	17.33
8	2e	Low tire heating	17.00
9	4d	60% effective spoilers	16.00
10	1a	Maximum landing weight	14.33
	3a	Brake application speed + 10%	14.33
12	5f	50% of full metered pressure	11.33
13	1b	Minimum landing weight	10.33
14	4b	Spoiler deployment at 2.0 sec	10.00
	d	Move dynamic breakpoint in 50% of nominal	10.00
16	2b	Tire inflation pressure 80% of nominal	8.67
17	2a	Tire inflation pressure 120% of nominal	7.00
18	1g	Torque gain 120% of nominal	6.67
19	4a	Spoiler deployment at 1.0 sec	6.00
	b	Increase line diameter by 50%	6.00
21	g	Increase brake p-v gain	5.67
22	2c	Forward center of gravity	5.33
23	2a	Hot day	5.00
	2b	Cold day	5.00
	1j	Linear torque gain	5.00
	a	Decrease line diameter by 50%	5.00
27	1h	Torque gain 80% of nominal	4.00
28	5e	75% of full metered pressure	3.33
29	1j	Variable torque gain	3.00
30	c	Move dynamic breakpoint out 150% of nominal . . .	2.67
	e	Insert 20% restriction in return line	2.67
32	4g	80% engine idle thrust	2.33
33	2d	Aft center of gravity	2.00
	4f	120% engine idle thrust	2.00

Table 31.—C-141 Parameter Ratings (Concluded)

Rank	Test condition	Description	Parameter rating index
	1f	Torque response breakpoint 50% of nominal	2.00
	3c	Maximum strut frequency varying stiffness	2.00
37	2d	80% worn tire	1.67
	3a	Maximum strut frequency varying mass	1.67
	3b	Minimum strut frequency varying mass	1.67
40	1e	Torque response breakpoint 150% of nominal	1.33
	3d	Minimum strut frequency varying stiffness	1.33
42	3a	Rough runway surface	1.00
	f	Increase brake volume by 10 cu in.	1.00
44	1c	Torque response 150% of running	0.67
	2c	50% worn tire	0.67
	3f	Vertical stiffness 80% of nominal	0.67
47	1a	High fade brake	0.50
48	1d	No torque peaking	0.33
	3h	Vertical damping 80% of nominal	0.33
50	1b	Low fade brake	0
	3e	Vertical stiffness 120% of nominal	0
	3q	Vertical damping 120% of nominal	0

Table 32.—F-4 Parameter Ratings

Rank	Test condition	Description	Parameter rating index
1	4c	No spoilers or drag devices	63.00
2	1b	20 knot wind	34.00
3	4a	40% effective spoilers	33.67
4	g	Increase brake p-v gain	28.33
5	5f	50% full metered pressure	24.67
6	3b	Brake application speed + 20%	23.33
7	1c	-10 knot wind	22.67
8	4d	60% effective spoilers	21.00
9	c	Move dynamic breakpoint out 150% of nominal . . .	19.33
10	1a	10 knot wind	19.00
11	5e	75% full metered pressure	15.33
12	2b	Tire inflation pressure 80% of nominal	15.00
13	1a	Maximum landing weight	14.67
14	3a	Brake application speed + 10%	13.33
15	1h	Torque gain 80% of nominal	13.00
16	2b	Cold day	12.67
17	4f	120% engine idle thrust	11.67
	2a	Tire inflation pressure 120% of nominal	11.67
19	b	Increase line diameter by 50%	11.33
20	1g	Torque gain 120% of nominal	10.67
21	2a	Hot day	10.33
22	1j	Linear torque gain	10.00
23	2d	80% worn tire	9.33
24	1i	Variable torque gain	9.00
25	4b	Drag device deployment at 2.0 sec	8.00
26	d	Move dynamic breakpoint in 50% of nominal	7.67
27	4g	80% engine idle thrust	7.33
28	2c	50% worn tire	6.00
29	4a	Drag device deployment at 1.0 sec	5.33
30	5d	Nominal pressure rate at 4.0 sec	5.00
	f	Increase brake volume by 10 cu in.	5.00
32	2f	Flat mu-slip peak	4.00
33	2c	Forward center of gravity	3.33
34	1b	Minimum landing weight	3.00

Table 32.—F-4 Parameter Ratings (Concluded)

Rank	Test condition	Description	Parameter rating index
	1e	Torque response breakpoint 150% of nominal	3.00
	2e	Low tire heating	3.00
37	2d	Aft center of gravity	2.33
	5c	Nominal pressure rate at 2.0 sec	2.33
	1f	Torque response breakpoint 50% of nominal	2.33
40	3b	Minimum strut frequency varying mass	2.00
41	3d	Minimum strut frequency varying stiffness	1.67
	3e	Vertical stiffness 120% of nominal	1.67
43	3c	Maximum strut frequency varying stiffness	1.33
44	1d	No torque peaking	1.00
	e	Insert 20% restriction in return line	1.00
46	5a	150% nominal pressure application rate	0.67
	1c	Torque peaking 150% of running	0.67
	3g	Vertical damping 120% of nominal	0.67
49	1a	High fade brake	0.50
50	5b	50% nominal pressure application rate	0.33
	3a	Rough runway surface	0.33
	3a	Maximum strut frequency varying mass	0.33
	3f	Vertical stiffness 80% of nominal	0.33
54	1b	Low fade brake	0
	3h	Vertical damping 80% of nominal	0

SECTION XIII

CALCULATION OF PI TERMS

Tables 33, 34, and 35 contain information needed to calculate various pi terms. The data consists of baseline values as well as values used in the brake system simulation parametric study. Tables 36 through 40 show the actual calculation steps to obtain pi terms for each condition and all airplane models. The calculations for π_1, π_2, and π_3 are straightforward. For π_4 calculations, the term F_e was obtained using the following relationship:

$$F_e = F_{eo} + \frac{KE}{2}\left(v + v_{stop}\right)$$

where:

F_{eo} = engine idle thrust at zero velocity

KE = change of idle thrust with velocity

v_{stop} = velocity at which stopping distance calculation was stopped on the simulator

Table 33.—Baseline Values Used in Airplane Simulation and Prediction Model

Airplane Parameter		Airplane				
Symbol	Units	727-200	737 Advanced	747-200	C-141A	F-4E
C_D	---	0.253	0.275	0.18	0.223	0.32
C_L	---	0.140	0.242	0.67	0.262	0.27
F_{eo}	lbf	2475	1200	9480	3600	1260
KE	lbf-sec/ft	-6.37	2.0	17.1	-6.94	-4.98
ρ	lbf-sec^2/ft^4	0.00238	0.00238	0.00238	0.00238	0.00238
v	fps	195	173	219	200	256
v_{stop}	fps	24	24	24	24	24
W	lbf	125000	85000	510000	260000	35000

Table 34.—Parametric Study Data

Test condition and airplane parameter changed	Airplane				
	727-200	737 Advanced	747-200	C-14A	F-4E
1a. Maximum landing weight					
W	137500	103000	564000	300000	46000
v	203	198	231	218	292
1b Minimum landing weight					
W	100000	70000	400000	180000	30000
v	174	165	194	167	237
3a. Brake application speed + 10%					
v	214	190.3	230	220	282
3b. Brake application speed + 20%					
v	234	207.6	241	240	308
4c. *No spoiler or drag device*					
C_L	1.36	1.512	1.15	1.10	0.27
C_D	0.167	0.194	0.1317	0.1145	0.11
4d. 60% effective spoilers					
C_L	0.628	0.748	0.862	0.597	0.27
C_D	0.2186	0.242	0.1607	0.179	0.228
4e. 40% effective spoilers					
C_L	0.872	1.003	0.958	0.765	0.27
C_D	0.2014	0.216	0.151	0.158	0.192

Table 34.—Parametric Study Data (Concluded)

Test condition and airplane parameter changed	Airplane				
	727-200	737 Advanced	747-200	C-141	F-4E
4f. 120% engine idle thrust					
F_{eo}	2970	1440	11375	4320	1510
KE	-5.1	2.4	20.5	-5.55	-4.0
4g. 80% engine idle thrust					
F_{eo}	1980	960	7854	2880	1010
KE	-7.65	1.6	13.7	-8.33	-6.0

Table 35.—Simulator Braking Distance Results

[Stopping Distance (Braking Segment Only) (ft)]

Condition	727			737			747			C-141			F-4		
Available Mu	0.6	0.4	0.2	0.6	0.4	0.2	0.6	0.4	0.2	0.6	0.4	0.2	0.6	0.4	0.2
Baseline	1278	1750	4192	1068	1440	2454	1905	2630	4598	1841	2752	5650	2766	3974	8593
Max wt	1400	1921	4579	1396	1856	3126	2090	2891	5040	2158	3102	6369	3255	4880	8832
Min wt	1051	1525	4226	960	1302	2231	1528	2137	3774	1652	2718	4602	2704	3841	8271
+ 10% v	1473	2003	5013	1266	1697	2850	2112*	2910*	5036*	2144	3173	6274	3370	4566	8825
+ 20% v	1685	2304	5537	1465	1956	3234	2334**	3201**	5469**	2466	3580	6851	3907	5022	8885
60% SP	1429	2034	5089	1210	1643	2819	2085	2908	5135	2139	3214	6506	3215	4850	10738
40% SP	1559	2376	5560	1313	1794	3122	2199	3066	5464	2340	3565	7050	3427	5326	12274
No SP	2306	3550	6926	1480	2040	-	2507	3491	6263	2948	4575	-	4095	7061	-
120% SP	1303	1776	4732	1067	1445	2492	1916	2661	4702	1866	2797	5836	2893	4196	10615
80% F_e	1273	1729	4055	1063	1430	2419	1868	2580	4438	1824	2703	5430	2722	3836	7218

* + 5% V_I

** + 10% V_I

Table 36.—727 Pi Determination

COND.	V	$\pi_2 = .6$		$\pi_2 = .5$		$\pi_2 = .4$		$\pi_2 = .3$		$\pi_2 = .2$	
		s	sg/V^2	s	sg/V^2	s	sg/V^2	s	sg/V^2	s	sg/V^2
	FPS	FT	π_1	FT	π_1	FT	π_1	FT	π_1	FT	π_1
BASE-LINE	195	1278	1.082	1456	1.233	1750	1.482	2250	1.905	4192	3.550

CONDITION	V	C.	C_D	C_L/C_D	$\pi_2 = .6$		$\pi_2 = .4$		$\pi_2 = .2$	
					s	sg/V^2	s	sg/V^2	s	sg/V^2
	FPS	—	—	π_3	FT	π_1	FT	π_1	FT	π_1
BASE LINE	195	.14	.253	.553	1278	1.082	1750	1.482	4192	3.55
60% SPOILERS	195	.628	.2186	2.87	1429	1.210	2034	1.722	5089	4.309
40% SPOILERS	195	.872	.2014	4.33	1559	1.320	2376	2.012	5560	4.708
NO SPOILERS	195	1.36	.167	8.144	2306	1.953	3550	3.006	6926	5.685

CONDITION	V	Feo	Fe	$\frac{\rho V^6}{Fe g^2}$	$\pi_2 = .6$		$\pi_2 = .4$		$\pi_2 = .2$	
					s	sg/V^2	s	sg/V^2	s	sg/V^2
	FPS	Lbf	Lbf	π_4	FT	π_1	FT	π_1	FT	π_1
BASELINE	195	2475	1777	71127	1278	1.082	1750	1.482	4192	3.55
MAX. WT	208	2475	1777	106378	1400	1.042	1921	1.430	4579	3.408
MIN. WT	174	2475	1777	36400	1051	1.118	1525	1.622	[illegible]	4.494
+10% V	214	2475	1777	127746	1473	1.026	2003	1.395	5013	3.492
+20% V	234	2475	1777	212394	1685	0.991	2304	1.355	5537	3.256
120% Fe	195	2970	2412	52331	1303	1.103	1776	1.504	4732	4.007
80% Fe	195	1980	1137	110989	1273	1.077	1729	1.464	4055	3.434

Table 37.—737 Pi Determination

COND.	V	$\pi_2 = .6$		$\pi_2 = .5$		$\pi_2 = .4$		$\pi_2 = .3$		$\pi_2 = .2$	
		S	Sg/V^2	S	Sg/V^2	S	Sg/V^2	S	Sg/V^2	S	Sg/V^2
	FPS	FT	π_1	FT	π_1	FT	π_1	FT	π_1	FT	π_1
BASE-LINE	173	1068	1.149	1215	1.307	1440	1.549	1797	1.932	2454	2.640

CONDITION	V	C_L	C_D	C_L/C_D	$\pi_2 = .6$		$\pi_2 = .4$		$\pi_2 = .2$	
					S	Sg/V^2	S	Sg/V^2	S	Sg/V^2
	FPS	—	—	π_3	FT	π_1	FT	π_1	FT	π_1
BASE LINE	173	.242	.275	.880	1068	1.149	1440	1.549	2454	2.64
60% SPOILERS	173	.748	.242	3.093	1210	1.302	1643	1.767	2819	3.03
40% SPOILERS	173	1.003	.216	4.643	1313	1.412	1794	1.930	3122	3.359
NO SPOILERS	173	1.512	.194	7.794	1480	1.595	2040	2.195	-	-

CONDITION	V	Feo	Fe	$\frac{\rho V^6}{Fe\,g^2}$	$\pi_2 = .6$		$\pi_2 = .4$		$\pi_2 = .2$	
					S	Sg/V^2	S	Sg/V^2	S	Sg/V^2
	FPS	Lbf	Lbf	π_4	FT	π_1	FT	π_1	FT	π_1
BASELINE	173	1200	1397	44146	1068	1.149	1440	1.549	2454	2.640
MAX. WT	198	1200	1397	99481	1396	1.146	1856	1.524	3126	2.567
MIN. WT	165	1200	1397	33266	960	1.135	1302	1.540	2231	2.639
+10% V	190	1200	1397	77439	1266	1.129	1697	1.514	2850	2.542
+20% V	207	1200	1397	129573	1465	1.100	1956	1.470	3234	2.430
120% Fe	173	1440	1674	36751	1067	1.148	1445	1.555	2492	2.681
80% Fe	173	960	1113	55267	1063	1.143	1430	1.538	2419	2.602

Table 38.—747 Pi Determination

COND.	V	$\pi_2 = .6$		$\pi_2 = .5$		$\pi_2 = .4$		$\pi_2 = .3$		$\pi_2 = .2$	
		s	sg/V^2	s	sg/V^2	s	sg/V^2	s	sg/V^2	s	sg/V^2
	FPS	FT	π_1	FT	π_1	FT	π_1	FT	π_1	FT	π_1
BASE-LINE	219	1905	1.279	2206	1.480	2630	1.766	3307	2.220	4598	3.087

CONDITION	V	C_L	C_D	C_L/C_D	$\pi_2 = .6$		$\pi_2 = .4$		$\pi_2 = .2$	
					s	sg/V^2	s	sg/V^2	s	sg/V^2
	FPS	—	—	π_3	FT	π_1	FT	π_1	FT	π_1
BASELINE	219	.67	.18	3.722	1905	1.279	2630	1.766	4598	3.087
60% SPOILERS	219	.862	.1607	5.364	2085	1.400	2908	1.952	5135	3.447
40% SPOILERS	219	.958	.151	6.344	2199	1.476	3066	2.058	5464	3.668
NO SPOILERS	219	1.15	.1317	8.732	2507	1.683	3491	2.344	6263	4.205

CONDITION	V	Feo	Fe	$\frac{\rho V^6}{Fe g^2}$	$\pi_2 = .6$		$\pi_2 = .4$		$\pi_2 = .2$	
					s	sg/V^2	s	sg/V^2	s	sg/V^2
	FPS	Lbf	Lbf	π_4	FT	π_1	FT	π_1	FT	π_1
BASELINE	219	9480	11557	21850	1905	1.279	2630	1.766	4598	3.087
MAX. WT	231	9480	11557	29711	2090	1.261	2891	1.744	5040	3.041
MIN. WT	194	9480	11557	10444	1528	1.307	2137	1.828	3774	3.229
+10% V	230	9480	11557	29339	2112	1.285	2910	1.771	5036	3.065
+20% V	241	9480	11557	38810	2334	1.294	3201	1.775	5469	3.032
120% Fe	219	11375	13872	18235	1916	1.286	2661	1.786	4702	3.157
80% Fe	219	7584	9231	27403	1868	1.254	2580	1.732	4438	2.979

Table 39.—C-141 Pi Determination

COND.	V	$\pi_2 = .6$		$\pi_2 = .5$		$\pi_2 = .4$		$\pi_2 = .3$		$\pi_2 = .2$	
		S	Sg/V^2	S	Sg/V^2	S	Sg/V^2	S	Sg/V^2	S	Sg/V^2
	FPS	FT	π_1	FT	π_1	FT	π_1	FT	π_1	FT	π_1
BASE-LINE	200	1841	1.482	2223	1.789	2752	2.215	3814	3.069	5650	4.548

CONDITION	V	C_L	C_D	C_L/C_D	$\pi_2 = .6$		$\pi_2 = .4$		$\pi_2 = .2$	
					S	Sg/V^2	S	Sg/V^2	S	Sg/V^2
	FPS	—	—	π_3	FT	π_1	FT	π_1	FT	π_1
BASELINE	200	.2615	.2226	1.175	1841	1.482	2752	2.215	5650	4.548
60% SPOILERS	200	.5969	.1790	3.332	2139	1.722	3214	2.587	6506	5.237
40% SPOILERS	200	.7646	.1580	4.839	2340	1.884	3565	2.870	7050	5.675
NO SPOILERS	200	1.10	.1146	9.607	2948	2.373	4575	3.683	-	-

CONDITION	V	Feo	Fe	$\frac{\rho V^6}{Fe g^2}$	$\pi_2 = .6$		$\pi_2 = .4$		$\pi_2 = .2$	
					S	Sg/V^2	S	Sg/V^2	S	Sg/V^2
	FPS	Lbf	Lbf	π_4	FT	π_1	FT	π_1	FT	π_1
BASELINE	200	3600	2823	52319	1841	1.482	2752	2.215	5650	4.548
MAX. WT	218	3600	2823	86421	2158	1.462	3102	2.102	6369	4.315
MIN. WT	167	3600	2823	17421	1652	1.907	2718	3.138	4602	5.313
+10% V	220	3600	2823	92685	2144	1.426	3173	2.111	6274	4.174
+20% V	240	3600	2823	156204	2466	1.378	3580	2.001	6851	3.830
120% Fe	200	4320	3692	39789	1866	1.502	2797	2.251	5836	4.698
80% Fe	200	2880	1950	75333	1824	1.468	2703	2.176	5430	4.371

Table 40.—F-4 Pi Determination

COND.	V	π_2 = .6		π_2 = .5		π_2 = .4		π_2 = .3		π_2 = .2	
		s	sg/V^2	s	sg/V^2	s	sg/V^2	s	sg/V^2	s	sg/V^2
	FPS	FT	π_1	FT	π_1	FT	π_1	FT	π_1	FT	π_1
BASE-LINE	256	2766	1.359	3273	1.608	3974	1.952	5261	2.585	8593	4.222

CONDITION	V	C_L	C_D	C_L/C_D	π_2 = .6		π_2 = .4		π_2 = .2	
					s	sg/V^2	s	sg/V^2	s	sg/V^2
	FPS	—	—	π_3	FT	π_1	FT	π_1	FT	π_1
BASE LINE	256	.27	.319	.846	2766	1.359	3974	1.952	8593	4.222
60% SPOILERS	256	.27	.228	1.184	3215	1.579	4850	2.383	10738	5.276
40% SPOILERS	256	.27	.192	1.406	3427	1.684	5326	2.617	12274	6.031
NO SPOILERS	256	.27	.110	2.454	4095	2.012	7061	3.469	-	-

CONDITION	V	Feo	Fe	$\frac{\rho V^6}{Fe g^2}$	π_2 = .6		π_2 = .4		π_2 = .2	
					s	sg/V^2	s	sg/V^2	s	sg/V^2
	FPS	Lbf	Lbf	π_4	FT	π_1	FT	π_1	FT	π_1
BASELINE	256	1260	563	1146583	2766	1.359	3974	1.952	8593	4.222
MAX. WT	292	1260	563	2535409	3255	1.229	4880	1.843	8832	3.335
MIN. WT	237	1260	563	725280	2704	1.55	3841	2.202	8271	4.741
+10% V	282	1260	563	2048633	3370	1.364	4566	1.849	8825	3.573
+20% V	308	1260	563	3477515	3907	1.324	5022	1.705	8885	3.016
120% Fe	256	1510	948	681181	2893	1.421	4196	2.062	10615	5.215
80% Fe	256	1010	160	3845833	2722	1.337	3836	1.885	7218	3.546

SECTION XIV

ARRANGEMENT OF PI TERMS

The experimental data converted to nondimensional pi terms must be arranged so that all of the pi terms containing independent variables, except one, remain constant. The remaining term is then varied to establish a relationship between it and π_1, the term containing the dependent variable. This procedure is repeated for each of the independently variable pi terms in the function. Tables 41 through 45 show the arrangement for each of the five airplanes. Each page is a complete data set with three sets per table to show the data at 0.6μ, 0.4μ, and 0.2μ conditions.

Table 41.—727 Pi Arrangement

INDEPENDENT π TERM	DEPENDENT π TERM	π TERMS HELD CONSTANT		
(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.6	1.082	.553	71127	BASELINE
.5	1.233			
.4	1.482			
.3	1.905			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
.553	1.082	.6	71127	BASELINE
2.97	1.210			60% SPOILERS
4.33	1.320			40% SPOILERS
8.144	1.953			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
36400	1.118	.6	.553	MINIMUM WEIGHT
52331	1.103			120% THRUST
71127	1.082			BASELINE
106378	1.042			MAXIMUM WEIGHT
110989	1.077			80% THRUST
127746	1.026			110% V_I
212394	0.991			120% V_I

Table 41.—727 Pi Arrangement (Continued)

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.6	1.082	.553	71127	BASELINE
.5	1.233			
.4	1.482			
.3	1.905			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
.553	1.482	.4	71127	BASELINE
2.87	1.722			60% SPOILERS
4.33	2.012			40% SPOILERS
8.144	3.006			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
36400	1.622	.4	.553	MINIMUM WEIGHT
52331	1.504			120% THRUST
71127	1.482			BASELINE
106378	1.430			MAXIMUM WEIGHT
110989	1.464			80% THRUST
127746	1.395			110% V_I
212394	1.355			120% V_I

Table 41.–727 Pi Arrangement (Concluded)

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.3	2.175	.553	71127	BASELINE
.275	2.400			
.25	2.65			
.225	2.975			
.2	3.550			
.167	4.242			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
.553	3.55	.2	71127	BASELINE
2.87	4.309			60% SPOILERS
4.33	4.708			40% SPOILERS
8.144	5.865			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
36400	4.494	.2	.553	MINIMUM WEIGHT
52331	4.007			120% THRUST
71127	3.550			BASELINE
106378	3.408			MAXIMUM WEIGHT
110989	3.434			80% THRUST
127746	3.492			110% V_I
212394	3.256			120% V_I

Table 42.—737 Pi Arrangement

(π_2)	(π_1)	$\bar{\pi}_3$	$\bar{\pi}_4$	CONDITION
.6	1.149	.88	44146	BASELINE
.5	1.307			
.4	1.549			
.3	1.932			
.2	2.640			
.1	4.500			

(π_3)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_4$	CONDITION
.88	1.149	.6	44146	BASELINE
3.093	1.302			60% SPOILERS
4.643	1.412			40% SPOILERS
7.794	1.595			NO SPOILERS

(π_4)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_3$	CONDITION
33266	1.135	.6	.88	MINIMUM WEIGHT
36751	1.148			120% THRUST
44146	1.149			BASELINE
99481	1.146			MAXIMUM WEIGHT
55267	1.143			80% THRUST
77439	1.129			110% V_I
129573	1.100			120% V_I

Table 42.--737 Pi Arrangement (Continued)

(π_2)	(π_1)	$\bar{\pi}_3$	$\bar{\pi}_4$	CONDITION
.6	1.149	.88	44146	BASELINE
.5	1.307			
.4	1.549			
.3	1.932			
.2	2.640			
.1	4.500			

(π_3)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_4$	CONDITION
.88	1.549	.4	44146	BASELINE
3.093	1.767			60% SPOILERS
4.643	1.930			40% SPOILERS
7.794	2.195			NO SPOILERS

(π_4)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_3$	CONDITION
33266	1.540	.4	.88	MINIMUM WEIGHT
36751	1.555			120% THRUST
44146	1.549			BASELINE
99481	1.524			MAXIMUM WEIGHT
55267	1.538			80% THRUST
77439	1.514			110% V_I
129573	1.470			120% V_I

Table 42.—737 Pi Arrangement (Concluded)

(π_2)	(π_1)	$\bar{\pi}_3$	$\bar{\pi}_4$	CONDITION
.6	1.149	.88	44146	BASELINE
.5	1.307			
.4	1.549			
.3	1.932			
.2	2.640			
.1	4.500			

(π_3)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_4$	CONDITION
.88	2.64	.2	44146	BASELINE
3.093	3.03			60% SPOILERS
4.643	3.359			40% SPOILERS
7.794	3.717			NO SPOILERS

(π_4)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_3$	CONDITION
33266	2.639	.2	.88	MINIMUM WEIGHT
36751	2.681			120% THRUST
44146	2.640			BASELINE
99481	2.567			MAXIMUM WEIGHT
55267	2.602			80% THRUST
77439	2.542			110% V_I
129573	2.430			120% V_I

Table 43.—747 Pi Arrangement

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.6	1.279	3.722	21850	BASELINE
.5	1.480			
.4	1.766			
.3	2.220			
.2	3.087			
.1	5.520			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
3.722	1.279	.6	21850	BASELINE
5.364	1.400			60% SPOILERS
6.344	1.476			40% SPOILERS
8.732	1.683			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
10444	1.307	.6	3.722	MINIMUM WEIGHT
18235	1.286			120% THRUST
21850	1.279			BASELINE
29711	1.261			MAXIMUM WEIGHT
27403	1.254			80% THRUST
29339	1.285			105% V_I
38810	1.294			110% V_I

Table 43.—747 Pi Arrangement (Continued)

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.6	1.279	3.722	21850	BASELINE
.5	1.480			
.4	1.766			
.3	2.220			
.2	3.087			
.1	5.520			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
3.722	1.766	.4	21850	BASELINE
5.364	1.952			60% SPOILERS
6.344	2.058			40% SPOILERS
8.732	2.344			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
10444	1.828	.4	3.722	MINIMUM WEIGHT
18235	1.786			120% THRUST
21850	1.766			BASELINE
29711	1.744			MAXIMUM WEIGHT
27403	1.732			80% THRUST
29339	1.771			105% V_I
38810	1.775			110% V_I

Table 43.—747 Pi Arrangement (Concluded)

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.6	1.279	3.722	21850	BASELINE
.5	1.480			
.4	1.766			
.3	2.220			
.2	3.087			
.1	5.520			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
3.722	3.087	.2	21850	BASELINE
5.364	3.447			60% SPOILERS
6.344	3.668			40% SPOILERS
8.732	4.205			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
10444	3.229	.2	3.722	MINIMUM WEIGHT
18235	3.157			120% THRUST
21850	3.087			BASELINE
29711	3.041			MAXIMUM WEIGHT
27403	2.979			80% THRUST
29339	3.065			105% V_I
38810	3.032			110% V_I

Table 44.—C-141 Pi Arrangement

(π_2)	(π_1)	$\bar{\pi}_3$	$\bar{\pi}_4$	CONDITION
.6	1.482	1.175	52319	BASELINE
.5	1.789			
.4	2.215			
.3	3.069			
.2	4.548			
.1	–			

(π_3)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_4$	CONDITION
1.175	1.482	.6	52319	BASELINE
3.332	1.722			60% SPOILERS
4.839	1.884			40% SPOILERS
9.607	2.373			NO SPOILERS

(π_4)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_3$	CONDITION
17421	1.907	.6	1.175	MINIMUM WEIGHT
39789	1.502			120% THRUST
52319	1.482			BASELINE
86421	1.462			MAXIMUM WEIGHT
75333	1.468			80% THRUST
92685	1.426			110% V_I
156204	1.378			120% V_I

Table 44.—C-141 Pi Arrangement (Continued)

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.6	1.482	1.175	52319	BASELINE
.5	1.789			
.4	2.215			
.3	3.069			
.2	4.548			
.1	–			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
1.175	2.215	.4	52319	BASELINE
3.332	2.587			60% SPOILERS
4.839	2.870			40% SPOILERS
9.607	3.683			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
17421	3.138	.4	1.175	MINIMUM WEIGHT
39789	2.251			120% THRUST
52319	2.215			BASELINE
86421	2.102			MAXIMUM WEIGHT
75333	2.176			80% THRUST
92685	2.111			110% V_I
156204	2.001			120% V_I

Table 44.—C-141 P1 Arrrangement (Concluded)

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.6	1.482	1.175	52319	BASELINE
.5	1.789			
.4	2.215			
.3	3.069			
.2	4.548			
.1	–			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
1.175	4.548	.2	52319	BASELINE
3.332	5.237			60% SPOILERS
4.839	5.675			40% SPOILERS
9.607	7.389			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
17421	5.313	.2	1.175	MINIMUM WEIGHT
39789	4.698			120% THRUST
52319	4.548			BASELINE
86421	4.315			MAXIMUM WEIGHT
75333	4.371			80% THRUST
92685	4.174			110% V_I
156204	3.830			120% V_I

Table 45.—F-4 Pi Arrangement

(π_2)	(π_1)	$\bar{\pi}_3$	$\bar{\pi}_4$	CONDITION
.6	1.359	.846	1146583	BASELINE
.5	1.608			
.4	1.952			
.3	2.585			
	–			

(π_3)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_4$	CONDITION
0.846	1.359	.6	1146583	BASELINE
1.184	1.579			60% SPOILERS
1.406	1.684			40% SPOILERS
2.454	2.012			NO SPOILERS

(π_4)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_3$	CONDITION
775280	1.550	.6	.846	MINIMUM WEIGHT
681181	1.421			120% THRUST
1146583	1.359			BASELINE
2535409	1.229			MAXIMUM WEIGHT
3845833	1.337			80% THRUST
2048633	1.364			110% V_I
3477515	1.324			120% V_I

Table 45.—F-4 Pi Arrangement (Continued)

(π_2)	(π_1)	$\bar{\pi}_3$	$\bar{\pi}_4$	CONDITION
.6	1.359	.846	1146583	BASELINE
.5	1.608			
.4	1.952			
.3	2.585			
.1	–			

(π_3)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_4$	CONDITION
0.846	1.952	.4	1146583	BASELINE
1.184	2.383			60% SPOILERS
1.406	2.617			40% SPOILERS
2.454	3.469			NO SPOILERS

(π_4)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_3$	CONDITION
725280	2.202	.4	.846	MINIMUM WEIGHT
681181	2.062			120% THRUST
1146583	1.952			BASELINE
2535409	1.843			MAXIMUM WEIGHT
3845833	1.885			80% THRUST
2048633	1.849			110% V_I
8477515	1.705			120% V_I

Table 45.—F-4 Pi Arrangement (Concluded)

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.30	2.71	.846	1146583	BASELINE
.275	2.96			
.25	3.23			
.225	3.58			
.2	4.222			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
0.846	4.222	.2	1146583	BASELINE
1.184	5.276			60% SPOILERS
1.406	6.031			40% SPOILERS
2.454	–			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
725280	4.741	.2	.846	MINIMUM WEIGHT
681181	5.215	.		120% THRUST
1146583	4.222			BASELINE
2535409	3.335			MAXIMUM WEIGHT
3845833	3.546			80% THRUST
2048633	3.573			110% V_I
3477515	3.016			120% V_I

SECTION XV

FORMULATION OF MODEL EQUATIONS AND MODEL-TO-SIMULATOR CORRELATION CALCULATIONS

After the conditions have been met for the function to be a product, a prediction equation is formed by multiplying all component equations and the constant term C. That is:

$$(\pi_1) = C\ f_1\ (\pi_2, \bar{\pi}_3, \bar{\pi}_4)\ f_2\ (\bar{\pi}_2, \pi_3, \bar{\pi}_4)\ f_3\ (\bar{\pi}_2, \bar{\pi}_3, \pi_4)$$

Therefore, for the 727 airplane at $\bar{\pi}_2 = 0.6$: –

$$(\pi_1) = 0.8607 \left\{ 0.7048\ (\pi_2)^{-0.8196}\ 1.06869\ (\pi_3)^{\left[0.3125 - 0.3375\ \%\ SP\right]}\ 2.314\ (\pi_4)^{-0.06836} \right\}$$

or:

$$\boxed{(\pi_1) = 1.5001\ (\pi_2)^{-0.8196}\ (\pi_3)^{\left[0.3125 - 0.3375\ \%\ SP\right]}\ (\pi_4)^{-0.06836}} \qquad (1)$$

For the 727 at $\bar{\pi}_2 = 0.4$:

$$(\pi_1) = 0.4507 \left\{ 0.7048\ (\pi_2)^{-0.8196}\ 1.4882\ (\pi_3)^{\left[0.33562 - 0.32769\ \%\ SP\right]}\ 4.2724\ (\pi_4)^{-0.9409} \right\}$$

or:

$$\boxed{(\pi_1) = 2.0197\ (\pi_2)^{-0.8196}\ (\pi_3)^{\left[0.33562 - 0.32769\ \%\ SP\right]}\ (\pi_4)^{-0.09409}} \qquad (2)$$

And for the 727 at $\overline{\pi}_2 = 0.2$:

$$(\pi_1) = 0.07935 \left\{ 0.5648 (\pi_2)^{-1.125} \, 3.7262 \, (\pi_3)^{\left[0.21586 - 0.13473 \% SP\right]} \, 27.297 \, (\pi_4)^{-0.1768} \right\}$$

or:

$$\boxed{(\pi_1) = 4.558 \, (\pi_2)^{-1.125} \, (\pi_3)^{\left[0.21586 - 0.13473 \% SP\right]} \, (\pi_4)^{-0.1768}} \qquad (3)$$

This process was repeated for the other airplanes and corresponding prediction equations were obtained. The prediction equations were then used to calculate predicted stopping distance (π term) and compared with actual stopping distance (π term) for correlation. The difference between the two was converted to a percentage error based on the actual stopping distance (π term). Tables 46 through 50 illustrate this correlation comparison.

Table 46.—727 Model-to-Simulator Correlation

$$(\pi_1) = 1.5001(\pi_2)^{-.8196}\,(\pi_3)^{[.3125-.3675\%SP]}\,(\pi_4)^{-.06836}$$
$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.6	1.5001	1.5199	1.0149	.4059	1.078	1.082	-.4	BASELINE
"	"	"	"	.4533	1.049	1.042	+.7	MAX. WT.
"	"	"	"	.4877	1.128	1.118	+.9	MIN. WT.
"	"	"	"	.4476	1.036	1.026	+1.0	+10% V_I
"	"	"	"	.4323	1.000	0.991	+.9	+20% V_I
"	"	"	1.1230	.4659	1.193	1.210	-1.4	60% SP
"	"	"	1.2971	"	1.378	1.320	+4.4	40% SP
"	"	"	1.9260	"	2.046	1.953	+4.8	NO SP
"	"	"	1.0149	.4755	1.100	1.103	-.3	120% Fe
"	"	"	"	.4520	1.046	1.077	-2.9	80% Fe
.4	"	2.1191		.4659	1.503	1.482	+1.4	BASELINE
"	"	"	"	.4533	1.462	1.430	+2.2	MAX WT.
"	"	"	"	.4877	1.573	1.622	-3.0	MIN. WT.
"	"	"	"	.4476	1.444	1.395	+3.5	+10% V_I
"	"	"	"	.4323	1.394	1.355	+2.9	+20% V_I
"	"	"	1.1230	.4659	1.663	1.722	-3.4	60% SP
"	"	"	1.2971	"	1.921	2.012	-4.5	40% SP
"	"	"	1.9260	"	2.852	3.006	-5.0	NO SP
"	"	"	1.0149	.4755	1.534	1.504	+2.0	120% Fe
"	"	"	"	.4520	1.458	1.464	-.4	80% Fe

Table 46.—727 Model-to-Simulator Correlation (Continued)

$$(\pi_1) = 2.0197\,(\pi_2)^{-.8196}\,(\pi_3)^{[.309-.3011\,\%SP]}\,(\pi_4)^{-.09409}$$
$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	%ERROR	CONDITION
.6	2.0197	1.5199	.9953	.3495	1.068	1.082	-1.3	BASELINE
''	''	''	''	.3365	1.028	1.046	-1.7	MAX. WT.
''	''	''	''	.3722	1.137	1.118	+1.7	MIN. WT.
''	''	''	''	.3308	1.011	1.026	-1.5	+10% V_I
''	''	''	''	.3153	0.963	0.991	-2.8	+20% V_I
''	''	''	1.1449	.3495	1.229	1.210	+1.6	60% SP
''	''	''	1.3183	''	1.414	—	—	40% SP
''	''	''	1.9118	''	2.051	1.953	+5.0	NO SP
''	''	''	.9953	.3598	1.099	1.103	-.4	120% Fe
''	''	''	''	.3352	1.024	1.077	-4.9	80% Fe
.4	''	2.1191	''	.3495	1.489	1.482	+.5	BASELINE
''	''	''	''	.3365	1.433	1.430	+.2	MAX. WT.
''	''	''	''	.3722	1.585	1.622	-2.3	MIN. WT.
''	''	''	''	.3308	1.409	1.395	+1.0	+10% V_I
''	''	''	''	.3153	1.343	1.355	-.9	+20% V_I
''	''	''	1.1449	.3495	1.713	1.722	-.5	60% SP
''	''	''	1.3183	''	1.972	2.012	-2.0	40% SP
''	''	''	1.9118	''	2.860	3.006	-4.8	NO SP
''	''	''	.9953	.3598	1.533	1.504	+1.9	120% Fe
''	''	''	''	.3352	1.428	1.464	-2.4	80% Fe

Table 46.--727 Model-to-Simulator Correlation (Concluded)

$$(\pi_1) = 4.558\,(\pi_2)^{-1.125}\,(\pi_3)^{[.2158\,-\,.1347\,\%SP]}\,(\pi_4)^{-.1768}$$
$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.2	139.306	.2	.9531	.1387	3.683	3.55	+3.7	BASELINE
"	"	"	"	.1292	3.431	3.408	+.7	MAX. WT.
"	"	"	"	.1562	-	-	-	MIN. WT.
"	"	"	"	.1251	3.322	3.492	-4.9	+10% V_I
"	"	"	"	.1143	3.035	3.256	-6.8	+20% V_I
"	"	"	1.1530	.1387	4.455	4.309	+3.4	60% SP
"	"	"	1.2679	"	4.899	4.708	+4.0	40% SP
"	"	"	1.5726	"	6.027	5.865	+3.6	NO SP
"	"	"	.9531	.1465	3.890	4.007	-2.9	120% Fe
"	"	"	"	.1282	3.404	3.434	-.9	80% Fe

Table 47.—737 Model-to-Simulator Correlation

$$(\pi_1) = 0.9632\ (\pi_2)^{-.7647}\ (\pi_3)^{[.1567-.08113\%\,SP]}\ (\pi_4)^{-.01951}$$
$$= K\ (\pi_2)'\ (\pi_3)'\ (\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.6	0.9632	1.4779	.9904	[illegible]	[illegible]	[illegible]	-.4	BASELINE
"	"	"	"	.7989	[illegible]	[illegible]	-1.7	MAX. WT.
"	"	"	"	.8162	1.15[illegible]	[illegible]	+1.4	MIN. WT.
"	"	"	"	.8028	[illegible]	[illegible]	+.3	+10% V_I
"	"	"	"	.7948	[illegible]	[illegible]	+1.8	+20% V_I
"	"	"	1.1297	.8117	1.305	1.302	+.2	60% SP
"	"	"	1.2101	"	1.398	1.412	-1.0	40% SP
"	"	"	1.3795	"	1.594	1.595	0	NO SP
"	"	"	.9904	.8146	1.148	1.148	0	120% Fe
"	"	"	"	.8081	1.139	1.143	-.3	80% Fe
.4	"	2.0151	"	.8117	1.560	1.549	+.7	BASELINE
"	"	"	"	.7989	1.535	1.524	+.7	MAX. WT.
"	"	"	"	.8162	1.569	1.540	+1.9	MIN. WT.
"	"	"	"	.8028	1.543	1.514	+1.9	+10% V_I
"	"	"	"	.7948	1.527	1.470	+3.9	+20% V_I
"	"	"	1.1297	.8117	1.779	1.767	+.7	60% SP
"	"	"	1.2101	"	1.906	1.930	-1.2	40% SP
"	"	"	1.3795	"	2.173	2.195	-1.0	NO SP
"	"	"	0.9904	.8146	1.565	1.555	+.6	120% Fe
"	"	"	"	.8081	1.553	1.538	+1.0	80% Fe
.2	"	3.4237	"	.8117	2.650	2.640	+.4	BASELINE
"	"	"	"	.7989	2.608	2.567	+1.6	MAX. WT.
"	"	"	"	.8162	2.666	2.639	+1.0	MIN. WT.
"	"	"	"	.8028	2.622	2.542	+3.1	+10% V_I
"	"	"	"	.7948	2.595	2.430	+6.8	+20% V_I
"	"	"	1.1297	.8117	3.023	3.030	-.2	60% SP
"	"	"	1.2101	"	3.239	3.359	-3.6	40% SP
"	"	"	1.3795	"	3.633	-	-	NO SP
"	"	"	0.9904	.8146	2.659	2.681	-.8	120% Fe
"	"	"	"	.8081	2.639	2.602	+1.4	80% Fe

Table 47.—737 Model-to-Simulator Correlation (Continued)

$$(\pi_1) = 1.096\ (\pi_2)^{-.7647}\ (\pi_3)^{[.16655-.08663\%SP]}\ (\pi_4)^{-.03222}$$
$$= K\ (\pi_2)'\ (\pi_3)'\ (\pi_4)'$$

$\bar{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.6	1.096	1.4779	.9898	.7085	1.136	1.149	-1.1	BASELINE
"	"	"	"	.6902	1.107	1.146	-3.4	MAX. WT.
"	"	"	"	.7150	1.146	1.135	+1.0	MIN. WT.
"	"	"	"	.6958	1.116	1.129	-1.1	+10% V_I
"	"	"	"	.6843	1.097	1.100	-.3	+20% V_I
"	"	"	1.1381	.7085	1.306	1.302	+.3	60% SP
"	"	"	1.2245	"	1.405	1.412	-.5	40% SP
"	"	"	1.4077	"	1.616	1.595	+1.3	NO SP
"	"	"	.9898	.7127	1.143	1.148	-.4	120% Fe
"	"	"	"	.7034	1.128	1.143	-1.3	80% Fe
.4	"	2.0151	"	.7085	1.549	1.549	0	BASELINE
"	"	"	"	.6902	1.509	1.524	-1.0	MAX. WT.
"	"	"	"	.7150	1.563	1.540	+1.5	MIN. WT.
"	"	"	"	.6958	1.521	1.514	+.5	+10% V_I
"	"	"	"	.6843	1.496	1.470	+1.8	+20% V_I
"	"	"	1.1381	.7085	1.781	1.767	+.8	60% SP
"	"	"	1.2245	"	1.916	1.930	-.7	40% SP
"	"	"	1.4077	"	2.203	2.195	+.4	NO SP
"	"	"	.9898	.7127	1.558	1.555	+.2	120% Fe
"	"	"	"	.7034	1.538	1.538	0	80% Fe
.2	"	3.4237	.9898	.7085	2.632	2.640	-.3	BASELINE
"	"	"	"	.6902	2.564	2.567	-.1	MAX. WT.
"	"	"	"	.7150	2.655	2.639	+.6	MIN. WT.
"	"	"	"	.6958	2.584	2.542	+1.6	+10% V_I
"	"	"	"	.6843	2.542	2.430	+4.6	+20% V_I
"	"	"	1.1381	.7085	3.026	3.030	-.1	60% SP
"	"	"	1.2245	"	3.255	3.359	-3.1	40% SP
"	"	"	1.4077	"	3.743	-	-	NO SP
"	"	"	.9898	.7127	2.647	2.681	-1.3	120% Fe
"	"	"	"	.7034	2.613	2.602	+.4	80% Fe

Table 47.—737 Model-to Simulator Correlation (Concluded)

$$(\pi_1) = 1.4409\,(\pi_2)^{-.7647}\,(\pi_3)^{[.16391-.06279\%\,SP]}\,(\pi_4)^{-.05739}$$
$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\overline{\pi}}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.6	1.4409	1.47990	.9871	.5413	1.138	1.149	-.9	BASELINE
"	"	"	"	.5166	1.089	1.146	-4.9	MAX. WT.
"	"	"	"	.5501	1.156	1.135	+1.8	MIN. WT.
"	"	"	"	.5241	1.102	1.129	-2.4	+10% V_I
"	"	"	"	.5088	1.070	1.100	-2.7	+20% V_I
"	"	"	1.1533	.5413	1.329	1.302	+2.1	60% SP
"	"	"	1.2376	"	1.427	1.412	+1.1	40% SP
"	"	"	1.4003	"	1.614	1.595	+1.2	NO SP
"	"	"	.9871	.5470	1.150	1.148	+.2	120% Fe
"	"	"	"	.5343	1.123	1.143	-1.7	80% Fe
.4	"	2.0151	.9871	.5413	1.551	1.549	+.1	BASELINE
"	"	"	"	.5166	1.480	1.524	-2.9	MAX. WT.
"	"	"	"	.5501	1.577	1.540	+2.4	MIN. WT.
"	"	"	"	.5241	1.502	1.514	-.8	+10% V_I
"	"	"	"	.5088	1.458	1.470	-.8	+20% V_I
"	"	"	1.1533	.5413	1.813	1.767	+2.6	60% SP
"	"	"	1.2376	"	1.945	1.930	+.8	40% SP
"	"	"	1.4003	"	2.200	2.195	+.2	NO SP
"	"	"	.09871	.5470	1.568	1.555	+.8	120% Fe
"	"	"	"	.5343	1.531	1.538	-.4	80% Fe
.2	"	3.4237	0.9871	.5413	2.636	2.640	-.1	BASELINE
"	"	"	"	.5166	2.516	2.567	-2.0	MAX. WT.
"	"	"	"	.5501	2.679	2.639	+1.5	MIN. WT.
"	"	"	"	.5241	2.552	2.542	+.4	+10% V_I
"	"	"	"	.5088	2.478	2.430	+2.0	+ 20% V_I
"	"	"	1.1533	.5413	3.080	3.030	+1.6	60% SP
"	"	"	1.2376	"	3.305	3.359	-1.6	40% SP
"	"	"	1.4003	"	3.739	3.718	+.6	NO SP
"	"	"	.9871	.5470	2.664	2.681	-.6	120% Fe
"	"	"	"	.5343	2.602	2.602	0	80% Fe

Table 48.—747 Model-to-Simulator Correlation

$$(\pi_1) = .9539\,(\pi_2)^{-.815}\,(\pi_3)^{[14803-.11286\%SP]}\,(\pi_4)^{-.01676}$$
$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	%ERROR	CONDITION
.6	.9539	1.5164	1.0473	.8458	1.281	1.279	-.1	BASELINE
"	"	"	"	.8415	1.275	1.261	-1.1	MAX. WT.
"	"	"	"	.8563	1.297	1.307	+.8	MIN. WT.
"	"	"	"	.8416	1.275	1.285	+.8	+10% V_I
"	"	"	"	.8377	1.269	1.294	+2.0	+20% V_I
"	"	"	1.1444	.8458	1.400	1.400	0	60% SP
"	"	"	1.2093	"	1.479	1.476	-.2	40% SP
"	"	"	1.3782	"	1.686	1.683	-.2	NO SP
"	"	"	1.0473	.8484	1.285	1.286	+.1	120% F_e
"	"	"	"	.8426	1.276	1.254	-1.7	80% F_e
.4	"	2.1102	1.0473	.8458	1.782	1.766	+.9	BASELINE
"	"	"	"	.8415	1.774	1.744	+1.7	MAX. WT.
"	"	"	"	.8563	1.805	1.828	-1.3	MIN. WT.
"	"	"	"	.8416	1.774	1.771	+.2	+10% V_I
"	"	"	"	.8377	1.766	1.775	-.5	+20% V_I
"	"	"	1.1444	.8458	1.948	1.952	-.2	60% SP
"	"	"	1.2093	"	2.058	2.058	0	40% SP
"	"	"	1.3782	"	2.346	2.344	+.1	NO SP
"	"	"	1.0473	.8484	1.788	1.786	+.1	120% F_e
"	"	"	"	.8426	1.775	1.732	+2.5	80% F_e
.2	"	.712	1.0473	.8458	3.136	3.087	+1.6	BASELINE
"	"	"	"	.8415	3.121	3.041	+2.6	MAX. WT.
"	"	"	"	.8563	3.175	3.2[illegible]9	-1.7	MIN. WT.
"	"	"	"	.8416	3.121	3.065	+1.8	+10% V_I
"	"	"	"	.8377	3.106	3.032	+2.4	+20% V_I
"	"	"	1.1444	.8458	3.427	3.447	-.6	60% SP
"	"	"	1.2093	"	3.620	3.668	-1.3	40% SP
"	"	"	1.3782	"	4.127	4.205	-1.8	NO SP
"	"	"	1.0473	.8484	3.145	3.157	-.4	120% F_e
"	"	"	"	.8426	3.123	2.979	+4.8	80% F_e

Table 48.—747 Model-to-Simulator Correlation (Continued)

$$(\pi_1) = .9974\ (\pi_2)^{-.815}\ (\pi_3)^{[.18957-.09193\text{[illegible]}]}\ (\pi_4)^{-.03004}$$
$$= K\ (\pi_2)'\ (\pi_3)'\ (\pi_4)'$$

$\bar{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	%ERROR	CONDITION
.6	.9974	1.5164	1.1369	.7407	1.274	1.279	-.4	BASELINE
"	"	"	"	.7339	1.262	1.261	0	MAX. WT.
"	"	"	"	.7573	1.302	1.307	-.4	MIN. WT.
"	"	"	"	.7342	1.264	1.283	-1.6	+10% V_I
"	"	"	"	.7280	1.252	1.294	-3.2	+20% V_I
"	"	"	1.2533	.7407	1.404	1.400	+.3	60% SP
"	"	"	1.3262	"	1.486	1.476	+.7	40% SP
"	"	"	1.5080	"	1.689	1.683	+.4	NO SP
"	"	"	1.1369	.7747	1.280	1.286	-.5	120% Fe
"	"	"	"	.7357	1.265	1.254	+.9	80% Fe
.4	"	2.1102	"	.7407	1.773	1.766	+.4	BASELINE
"	"	"	"	.7339	1.756	1.744	+.7	MAX. WT.
"	"	"	"	.7573	1.812	1.828	-.9	MIN. WT.
"	"	"	"	.7342	1.757	1.771	-.8	+10% V_I
"	"	"	"	.7280	1.742	1.775	-1.8	+20% V_I
"	"	"	1.2533	.7407	1.954	1.952	+.1	60% SP
"	"	"	1.3262	"	2.068	2.058	+.5	40% SP
"	"	"	1.5080	"	2.351	2.344	+.3	NO SP
"	"	"	1.1369	.7447	1.782	1.786	-.2	120% Fe
"	"	"	"	.7357	1.760	1.732	+1.6	80% Fe
.2	"	3.712	"	.7407	3.119	3.087	+1.0	BASELINE
"	"	"	"	.7339	3.089	3.041	+1.6	MAX. WT
"	"	"	"	.7573	3.187	3.229	-1.3	MIN. WT.
"	"	"	"	.7342	3.091	3.065	+.8	+10% V_I
"	"	"	"	.7280	3.064	3.032	+1.0	+20% V_I
"	"	"	1.2533	.7407	3.437	3.447	-.3	60% SP
"	"	"	1.3262	"	3.638	3.668	-.8	40% SP
"	"	"	1.5080	"	4.136	4.205	-1.6	NO SP
"	"	"	1.1369	.7447	3.135	3.157	-.7	120% Fe
"	"	"	"	.7357	3.096	2.979	+3.9	80% Fe

Table 48.—Model-to Simulator Correlation (Concluded)

$$(\pi_1) = 1.1897\,(\pi_2)^{-.815}\,(\pi_3)^{[.2365-.0818\,\%\,SP]}\,(\pi_4)^{-.05588}$$
$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\bar{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	%ERROR	CONDITION
.6	1.1897	1.5164	1.2255	.5721	1.264	1.279	-1.1	BASELINE
''	''	''	''	.5624	1.[illegible]3	1.261	-1.4	MAX. WT.
''	''	''	''	.5962	1.318	1.307	+.8	MIN. WT.
''	''	''	''	.5628	1.244	1.285	-3.2	+10% V_I
'	''	''	''	.5541	1.230	1.294	-5.0	+20% V_I
''	''	''	1.3699	.5721	1.414	1.400	+1.0	60% SP
''	''	''	1.4572	''	1.504	1.476	+1.9	40% SP
''	''	''	1.6694	''	1.723	1.683	+2.4	NO SP
''	''	''	1.2255	.5780	1.278	1.286	-.6	120% Fe
''	''	''	''	.5649	1.249	1.254	-.4	80% Fe
.4	''	2.1102	1.2255	.5721	1.760	1.766	-.4	BASELINE
''	''	''	''	.5624	1.730	1.744	-.8	MAX. WT.
''	''	''	''	.5962	1.834	1.828	+.3	MIN. WT.
''	''	''	''	.5628	1.732	1.771	-2.2	+10% V_I
''	''	''	''	.5541	1.705	1.775	-3.9	+20% V_I
''	''	''	1.3699	.5721	1.967	1.952	+.8	60% SP
''	''	''	1.4572	''	2.092	2.058	+1.6	40% SP
''	''	''	1.6694	''	2.398	2.344	+2.3	NO SP
''	''	''	1.2255	.5780	1.778	1.786	-.4	120% Fe
''	''	''	''	.5649	1.738	1.732	+.3	80% Fe
.2	''	3.712	1.2255	.5721	3.096	3.087	+.3	BASELINE
''	''	''	''	.5624	3.044	3.041	+.1	MAX. WT.
''	''	''	''	.5962	3.227	3.229	-.1	MIN. WT.
''	''	''	''	.5628	3.046	3.065	-.6	+10% V_I
''	''	''	''	.5541	2.999	3.032	-1.1	+20% V_I
''	''	''	1.3699	.5721	3.461	3.447	+.4	60% SP
''	''	''	1.4572	''	3.681	3.668	+.3	40% SP
''	''	''	1.6694	''	4.218	4.205	+.3	NO SP
''	''	''	1.2255	.5780	3.128	3.157	-.9	120% Fe
''	''	''	''	.5649	3.057	2.979	+2.6	80% Fe

Table 49.—C-141 Model-to-Simulator Correlation

$$(\pi_1) = 1.6814 \; (\pi_2)^{-1.0268} \; (\pi_3)^{[.21341-.13084\,\%SP]} \; (\pi_4)^{-.06129}$$

$$= K \; (\pi_2)' \; (\pi_3)' \; (\pi_4)'$$

$\bar{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	%ERROR	CONDITION
.6	1.6814	1.6896	1.0134	.5138	1.479	1.482	-.2	BASELINE
"	"	"	"	.4982	1.434	1.462	-1.9	MAX. WT.
"	"	"	"	.5496	1.582	-	-	MIN. WT.
"	"	"	"	.4961	1.428	1.427	+.1	+10% V_I
"	"	"	"	.4805	1.383	1.378	+.4	+20% V_I
"	"	"	1.1763	.5138	1.717	1.722	-.3	60% SP
"	"	"	1.2891	"	1.882	1.884	-.1	40% SP
"	"	"	1.6207	"	2.366	2.373	-.3	NO SP
"	"	"	1.0134	.5225	1.504	1.502	+.1	120% Fe
"	"	"	"	.5024	1.447	1.468	-1.4	80% Fe
.4	"	2.5621	"	.5138	2.243	2.215	+1.2	BASELINE
"	"	"	"	.4982	2.174	2.103	+3.4	MAX. WT.
"	"	"	"	.5496	2.399	-	-	MIN. WT.
"	"	"	"	.4961	2.165	2.111	+2.6	+10% V_I
"	"	"	"	.4805	2.097	2.001	+4.8	+20% V_I
"	"	"	1.1763	.5138	2.604	2.587	+.7	60% SP
"	"	"	1.2891	"	2.854	2.870	-.6	40% SP
"	"	"	1.6207	"	3.588	3.683	-2.6	NO SP
"	"	"	1.0134	.5225	2.281	2.251	+1.3	120% Fe
"	"	"	"	.5024	2.194	2.176	+.8	80% Fe
.2	"	5.220	1.0134	.5138	4.569	4.548	+.5	BASELINE
"	"	"	"	.4982	4.430	4.315	+2.7	MAX. WT.
"	"	"	"	.5496	4.888	-	-	MIN. WT.
"	"	"	"	.4961	4.412	4.174	+5.7	+10% V_I
"	"	"	"	.4805	4.273	3.830	-	+20% V_I
"	"	"	1.1763	.5138	5.305	5.237	+1.3	60% SP
"	"	"	1.2891	"	5.815	5.675	+2.5	40% SP
"	"	"	1.6207	"	7.310	-	-	NO SP
"	"	"	1.0134	.5225	4.647	4.698	-1.1	120% Fe
"	"	"	"	.5024	4.471	4.371	+2.3	80% Fe

Table 49.—C-141 Model-to-Simulator Correlation (Continued)

$$(\pi_1) = 2.20115(\pi_2)^{-1.0268}(\pi_3)^{[\qquad]}(\pi_4)^{-.08964}$$

$$= K\ (\pi_2)'\ (\pi_3)'\ (\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.6	2.20115	1.6896	1.0134	.3888	1.465	1.482	-1.1	BASELINE
"	"	"	"	.3722	1.403	1.462	-4.0	MAX. WT.
"	"	"	"	.4278	1.612	-	-	MIN. WT.
"	"	"	"	.3700	1.395	1.426	-2.2	+10% V_I
"	"	"	"	.3535	1.332	1.378	-3.3	+20% V_T
"	"	"	1.1860	.3888	1.715	1.722	-.4	60% SP
"	"	"	1.3102	"	1.895	1.884	+.6	40% SP
"	"	"	1.6851	"	2.438	2.373	+2.7	NO SP
"	"	"	1.0134	.3982	1.501	1.502	0	120% Fe
"	"	"	"	.3767	1.420	1.468	-3.3	80% Fe
.4	2.20115	2.5621	1.0134	.3888	2.222	2.215	+.3	BASELINE
"	"	"	"	.3722	2.127	2.102	+1.2	MAX WT.
"	"	"	"	.4278	2.445	-	-	MIN. WT
"	"	"	"	.3700	2.115	2.111	+.2	+10% V_I
"	"	"	"	.3535	2.020	2.001	+.9	+20% V_I
"	"	"	1.1860	.3888	2.600	2.587	+.5	60% SP
"	"	"	1.3102	"	2.873	2.870	+.1	40% SP
"	"	"	1.6851	"	3.695	3.683	+.3	NO SP
"	"	"	1.0134	.3982	2.276	2.251	+1.1	120% Fe
"	"	"	"	.3767	2.153	2.176	-1.0	80% Fe
.2	"	5.220	1.0134	.3888	4.527	4.548	-.5	BASELINE
"	"	"	"	.3722	4.333	4.315	+.4	MAX. WT.
"	"	"	"	.4278	4.981	-	-	MIN. WT.
"	"	"	"	.3700	4.309	4.174	+3.2	+10% V_I
"	"	"	"	.3535	4.115	-	-	+20% V_I
"	"	"	1.1860	.3888	5.297	5.237	+1.1	60% SP
"	"	"	1.3102	"	5.853	5.675	+3.1	40% SP
"	"	"	1.6851	"	7.528	-	-	NO SP
"	"	"	1.0134	.3982	4.637	4.698	-1.3	120% Fe
"	"	"	"	.3767	4.386	4.371	+.3	80% Fe

Table 49.—C-141 Model-to-Simulator Correlation (Concluded)

$$(\pi_1) = 4.116\ (\pi_2)^{-1.0268}\ (\pi_3)^{[\quad]}\ (\pi_4)^{-.14344}$$

$$= K\ (\pi_2)'\ (\pi_3)'\ (\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	%ERROR	CONDITION
.6	4.116	1.6896	1.0082	.2104	1.476	1.482	-.4	BASELINE
"	"	"	"	.1958	1.373	1.462	-6.0	MAX. WT.
"	"	"	"	.2464	1.727	-	-	MIN. WT.
"	"	"	"	.1939	1.359	1.426	-4.7	+10% V_I
"	"	"	"	.1799	1.261	1.378	-	+20% V_I
"	"	"	1.1508	.2104	1.684	1.722	-2.2	60% SP
"	"	"	1.2666	"	1.854	1.884	-1.6	40% SP
"	"	"	1.6307	"	2.386	2.373	+.5	NO SP
"	"	"	1.0082	.2189	1.535	1.502	+2.2	120% Fe
"	"	"	"	.1997	1.400	1.468	-4.6	80% Fe
.4	4.116	2.5621	1.0082	.2104	2.238	2.215	+1.0	BASELINE
"	"	"	"	.1958	2.082	2.102	-.9	MAX. WT.
"	"	"	"	.2464	2.619	-	-	MIN. WT.
"	"	"	"	.1939	2.061	2.111	-2.4	+10% V_I
"	"	"	"	.1799	1.913	2.001	-4.4	+20% V_I
"	"	"	1.1508	.2104	2.554	2.587	-1.3	60% SP
"	"	"	1.2666	"	2.811	2.870	-2.0	40% SP
"	"	"	1.6307	"	3.619	3.683	-1.7	NO SP
"	"	"	1.0082	.2189	2.327	2.251	3.4	120% Fe
"	"	"	"	.1997	2.123	2.176	-2.4	80% Fe
.2	4.116	5.22	1.0082	.2104	4.559	4.548	+.2	BASELINE
"	"	"	"	.1958	4.241	4.315	-1.7	MAX. WT.
"	"	"	"	.2464	5.337	-	-	MIN. WT.
"	"	"	"	.1939	4.200	4.174	+.6	+10% V_I
"	"	"	"	.1799	3.897	3.83	+1.7	+20% V_I
"	"	"	1.1508	.2104	5.204	5.237	-.6	60% SP
"	"	"	1.2666	"	5.727	5.675	+.9	40% SP
"	"	"	1.6307	"	7.373	-	-	NO SP
"	"	"	1.0082	.2189	4.742	4.698	+.9	120% Fe
"	"	"	"	.1997	4.326	4.371	-1.0	80% Fe

Table 50.—F-4 Model-to-Simulator Correlation

$$(\pi_1) = 1.679\,(\pi_2)^{-.9239}(\pi_3)^{[\,.3636\,]}(\pi_4)^{-.04408}$$

$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	%ERROR	CONDITION
.6	1.679	1.6031	.941	.5406	1.369	1.359	+.7	BASELINE
"	"	"	"	.5220	1.322	-	-	MAX. WT.
"	"	"	"	.5517	1.397	-	-	MIN. WT.
"	"	"	"	.5270	1.335	1.364	-2.1	+10% V_I
"	"	"	"	.5148	1.304	1.324	-1.5	+20% V_I
"	"	"	1.0633	.5406	1.547	1.579	-2.0	60% SP
"	"	"	1.1319	"	1.647	1.684	-2.2	40% SP
"	"	"	1.3860	"	2.017	2.012	+.2	NO SP
"	"	"	.941	.5532	1.401	1.421	-1.4	120% F_e
"	"	"	"	.5125	1.298	1.337	-2.9	80% F_e
.4	"	2.3316	"	.5406	1.991	1.952	+2.0	BASELINE
"	"	"	"	.5220	1.923	1.843	+4.3	MAX. WT.
"	"	"	"	.5517	2.032	–	-	MIN. WT.
"	"	"	"	.5270	1.942	1.848	+5.0	+10% V_I
"	"	"	"	.5148	1.897	1.705	-	+20% V_I
"	"	"	1.0633	.5406	2.250	2.383	-5.6	60% SP
"	"	"	1.1319	"	2.395	2.617	-8.5	40% SP
"	"	"	1.3860	"	2.934	3.469	-	NO SP
"	"	"	0.941	.5532	2.038	2.062	-1.2	120% F_e
"	"	"	"	.5125	1.888	1.885	+.2	80% F_e

Table 50.—F-4 Model-to-Simulator Correlation (Continued)

$$(\pi_1) = 2.8026\,(\pi_2)^{-.9239}\,(\pi_3)^{[\qquad]}\,(\pi_4)^{-.07895}$$

$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.6	2.8026	1.6031	.903	.3324	1.348	1.359	-.8	BASELINE
"	"	"	"	.3122	1.266	1.229	+3.0	MAX. WT.
"	"	"	"	.3446	1.398	-	-	MIN. WT.
"	"	"	"	.3175	1.288	1.364	-5.5	+10% V_I
"	"	"	"	.3045	1.235	1.324	-6.7	+20% V_I
"	"	"	1.1023	.3324	1.646	1.579	+4.2	60% SP
"	"	"	1.2103	"	1.807	1.684	+7.3	40% SP
"	"	"	1.6049	"	2.397	2.012	-	NO SP
"	"	"	.903	.3463	1.405	1.421	-1.1	120% Fe
"	"	"	"	.3021	1.226	1.337	-8.3	80% Fe
.4	2.8026	2.3316	.903	.3324	1.961	1.952	+.5	BASELINE
"	"	"	"	.3122	1.842	1.843	0	MAX. WT.
"	"	"	"	.3446	2.033	-	-	MIN. WT.
"	"	"	"	.3175	1.873	1.849	+1.3	+10% V_I
"	"	"	"	.3045	1.797	1.705	+5.4	+20% V_I
"	"	"	1.1023	.3324	2.394	2.383	+.5	60% SP
"	"	"	1.2103	"	2.629	2.617	+.5	40% SP
"	"	"	1.6049	"	3.486	3.469	+.5	NO SP
"	"	"	.903	.3463	2.043	2.062	-.9	120% Fe
"	"	"	"	.3021	1.783	1.885	-5.4	80% Fe

Table 50.—Model-to-Simulator Correlation (Concluded)

$$(\pi_1) = 31.52(\pi_2)^{-1.0694}(\pi_3)^{[.69738]}(\pi_4)^{-.260173}$$
$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.2	31.52	5.59	.8899	.02651	4.157	4.222	-1.5	BASELINE
"	"	"	"	.02157	3.382	3.335	+1.4	MAX. WT.
"	"	"	"	.02987	4.684	4.741	-1.2	MIN. WT.
"	"	"	"	.0228	3.573	3.573	0	+10% V_I
"	"	"	"	.01987	3.116	3.016	+3.3	+20% V_I
"	"	"	1.125	.02651	5.255	5.276	-.4	60% SP
"	"	"	1.2682	"	5.925	6.031	-1.7	40% SP
"	"	"	1.8702	"	8.737	-	-	NO SP
"	"	"	.8899	.03036	4.761	5.215	-8.7	120% F_e
"	"	"	"	.01935	3.034	3.456	-12.2	80% F_e

SECTION XVI

WET-RUNWAY ANALYSIS CALCULATIONS

The procedure followed in Sections XIII, XIV, and XV was repeated for the data analysis of wet runway conditions and prediction equations were obtained as before. However, a velocity-dependent mu value was converted into a constant peak available mu value (independent of velocity) by using previous π_1 vs π_2 component equations. For example, Eqs 8, 11, 18, 25, and 37 in ASD-TR-74-41, Volume I, Section XI. Tables 51 through 65 illustrate the steps involved.

Figure 51.—Wet Runway Data For Variable Mu = 0.05 to 0.5

CONDITION	STOPPING DISTANCE (BRAKING SEGMENT ONLY)				
	727	737	747	C-141	F-4
BASELINE	5009	3207	6809	5033	5890
MAX. WT.	5685	4580	7798	5942	7392
MIN WT.	3857	2770	5050	3781	5394
+ 10% V_I	5461	3883	7676	5733	6359
+ 20% V_I	5986	4652	8440	6361	6788
60% SP	-	3704	7885	-	7670
40% SP	-	4490	8607	-	8690
No SP	-	5165	10103	-	13185
120% Fe	5191	3265	7246	5200	6338
80% Fe	4747	3128	6543	4894	5451

Table 52.—Calculation of Pi Terms for Wet Runway

AIRPLANE	727			737			747			C-141			F-4		
	S	V	Sg/v^2	S	V	Sg/v^2	S	V	Sg/v^2	S	V	Sg/v^2	S	V	Sg/v^2
	FT.	FPS	-	FT.	FPS	-	FT.	FPS	-	FT.	FPS	-	FT.	FPS	-
CONDITION	-	-	(π_1)	-	-	(π_1)	-	-	(π_1)	-	-	(π_1)	-	-	(π_1)
BASELINE	5009	195	4.242	3207	173	3.450	6809	219	4.571	5033	200	4.052	5890	256	2.894
MAX. WT.	5685	208	4.231	4580	198	3.762	7798	231	4.706	5942	218	4.026	7392	292	2.792
MIN. WT.	3857	174	4.102	2770	165	3.276	5050	194	4.321	3781	167	4.365	5394	237	3.092
+10% V_I	5461	214	3.840	3883	190	3.463	7676	230	4.672	5733	220	3.814	6359	282	2.575
+20% V_I	5986	234	3.520	4652	207	3.496	8440	241	4.679	[illegible]	[illegible]	3.556	5789	308	2.304
60% SP	-	-	-	3704	173	3.985	7885	219	5.294	-	-	-	7670	256	3.768
40% SP	-	-	-	4490	173	4.831	8607	219	5.779	-	-	-	8690	256	4.270
NO SP	-	-	-	5165	173	5.557	10103	219	6.783	-	-	-	13185	256	6.478
20% F_e	5191	195	4.396	3265	173	3.513	7246	219	4.865	5200	200	4.186	6338	256	3.114
80 % F_e	4747	195	4.020	3128	173	3.365	6543	219	4.393	4894	200	3.940	5451	256	2.678

Table 53.—727 Pi Terms for Wet Runway

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.3	2.175	.553	71127	BASELINE
.275	2.400			
.25	2.65			
.225	2.975			
.2	3.550			
.167	4.242			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
.553	–	.167	71127	BASELINE
2.87	–			60% SPOILERS
4.33	–			40% SPOILERS
8.144	–			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
36400	4.102	.167	.553	MINIMUM WEIGHT
52331	4.396			120% THRUST
71127	4.242			BASELINE
106378	4.2312			MAXIMUM WEIGHT
110989	4.020			80% THRUST
127746	3.840			110% V_I
212394	3.520			120% V_I

Table 54.—737 Pi Terms for Wet Runway

(π_2)	(π_1)	$\bar{\bar{\pi}}_3$	$\bar{\bar{\pi}}_4$	CONDITION
.6	1.149	.88	44146	BASELINE
.5	1.307			
.4	1.549			
.3	1.932			
.2	2.640			
.1	4.500			

(π_3)	(π_1)	$\bar{\bar{\pi}}_2$	$\bar{\bar{\pi}}_4$	CONDITION
.88	3.450	.141	44146	BASELINE
3.093	3.985			60% SPOILERS
4.643	4.831			40% SPOILERS
7.794	5.557			NO SPOILERS

(π_4)	(π_1)	$\bar{\bar{\pi}}_2$	$\bar{\bar{\pi}}_3$	CONDITION
33266	3.276	.141	.88	MINIMUM WEIGHT
36751	3.496			120% THRUST
44146	3.450			BASELINE
99481	3.762			MAXIMUM WEIGHT
55267	3.365			80% THRUST
77439	3.463			110% V_I
129573	3.513			120% V_I

Table 55.—747 Pi Terms for Wet Runway

(π_2)	(π_1)	$\bar{\pi}_3$	$\bar{\pi}_4$	CONDITION
.6	1.279	3.722	21850	BASELINE
.5	1.480			
.4	1.766			
.3	2.220			
.2	3.087			
.1	5.520			

(π_3)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_4$	CONDITION
3.722	4.571	.125	21850	BASELINE
5.364	5.294			60% SPOILERS
6.344	5.779			40% SPOILERS
8.732	6.783			NO SPOILERS

(π_4)	(π_1)	$\bar{\pi}_2$	$\bar{\pi}_3$	CONDITION
10444	4.321	.125	3.722	MINIMUM WEIGHT
18235	4.865			120% THRUST
21850	4.571			BASELINE
29711	4.705			MAXIMUM WEIGHT
27403	4.393			80% THRUST
38810	4.679			105% V_I
18235	4.865			110% V_I

Table 56.—C-141 Pi Terms for Wet Runway

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.6	1.482	1.175	52319	BASELINE
.5	1.789			
.4	2.215			
.3	3.069			
.2	4.548			
.1	–			

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
1.175	4.052	.225	52319	BASELINE
3.332	–			60% SPOILERS
4.839	–			40% SPOILERS
9.607	–			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
17421	4.365	.225	1.175	MINIMUM WEIGHT
39789	4.186			120% THRUST
52319	4.052			BASELINE
86421	4.026			MAXIMUM WEIGHT
75333	3.940			80% THRUST
92685	3.814			110% V_I
156204	3.556			120% V_I

Table 57.—F-4 Pi Terms for Wet Runway

(π_2)	(π_1)	$\overline{\pi}_3$	$\overline{\pi}_4$	CONDITION
.30	2.71	.846	1146583	BASELINE
.275	2.96			
.25	3.23			
.225	3.58			
.2	4.222			
.1				

(π_3)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_4$	CONDITION
0.846	2.894	.278	1146583	BASELINE
1.184	3.768			60% SPOILERS
1.406	4.270			40% SPOILERS
2.454	6.478			NO SPOILERS

(π_4)	(π_1)	$\overline{\pi}_2$	$\overline{\pi}_3$	CONDITION
725280	3.092	.278	.846	MINIMUM WEIGHT
681181	3.114			120% THRUST
1146583	2.894			BASELINE
2535409	2.792			MAXIMUM WEIGHT
3845833	2.678			80% THRUST
2048633	2.575			110% V_I
3477515	2.304			120% V_I

Table 58.—Calculated Wet Runway Mu

Airplane model	$s_{braking}$	(π_2) vs (π_1) prediction Eq	Calculated (π_2) or μ
727	5009	$(\pi_1) = 0.5648\ (\pi_2)^{-1.125}$	0.167
737	3207	$(\pi_1) = 0.7716\ (\pi_2)^{-0.7647}$	0.141
747	6809	$(\pi_1) = 0.338\ (\pi_2)^{-0.815}$	0.125
C-141	5033	$(\pi_1) = 0.876\ (\pi_2)^{-1.0268}$	0.225
F-4	5890	$(\pi_1) = 0.7473\ (\pi_2)^{-1.0694}$	0.278

Table 59.—Summary of Wet Runway Component Equations and Constant Term Values

Airplane	Equation	Eq No.
727	$(\pi_1) = 0.5648\ (\pi_2)^{-1.125}$	(8)*
	$(\pi_1) = 4.5919\ (\pi_3)^{-0.1338}$	(4)
	$(\pi_1) = 11.9918\ (\pi_4)^{-0.09548}$	(5)
	$(C) = 0.05723$	
737	$(\pi_1) = 0.7716\ (\pi_2)^{-0.7647}$	(11)*
	$(\pi_1) = 3.4744\ (\pi_3)^{[0.23458 - 0.12654\ \%\ SP]}$	(6)
	$(\pi_1) = 2.0287\ (\pi_4)^{-0.04881}$	(7)
	$(C) = 0.06535$	
747	$(\pi_1) = 0.838\ (\pi_2)^{-0.815}$	(18)*
	$(\pi_1) = 3.1326\ (\pi_3)^{[0.35764 - 0.06953\ \%\ SP]}$	(8)
	$(\pi_1) = 2.9904\ (\pi_4)^{0.04275}$	(9)
	$(C) = 0.04774$	
C-141	$(\pi_1) = 0.876\ (\pi_2)^{-1.0268}$	(25)*
	$(\pi_1) = 4.015\ (\pi_3)^{0.0568}$	(10)

Table 59 —Summary of Wet Runway Component Equations and Constant Term Values (Concluded)

Airplane	Equation	Eq No.
C-141 (Cont.)	$(\pi_1) = 0.4417\ (\pi_4)^{-0.08735}$	(11)
	$(C) = 0.06104$	
F-4	$(\pi_1) = 0.7337\ (\pi_2)^{-1.0694}$	(37)*
	$(\pi_1) = 3.3012\ (\pi_3)^{[0.74982 + 0.03347\ \%\ SP]}$	(12)
	$(\pi_1) = 16.7349\ (\pi_4)^{-0.12555}$	(13)
	$(C) = 0.1194$	

* Equation taken from ASD-TR-74-41, Volume I, Section XI.

Table 60.—Summary of Wet Runway Prediction Equations

Airplane	Equation	Eq No.
727	$(\pi_1) = 1.7801\ (\pi_2)^{-1.125}\ (\pi_3)^{0.1338}\ (\pi_4)^{-0.09548}$	(14)
737	$(\pi_1) = 0.4642\ (\pi_2)^{-0.7647}\ (\pi_3)^{[0.23458 - 0.12654\ \%\ SP]}$ $\cdot (\pi_4)^{0.04881}$	(15)
747	$(\pi_1) = 0.3748\ (\pi_2)^{-0.815}\ (\pi_3)^{[0.35764 - 0.06953\ \%\ SP]}$ $\cdot (\pi_4)^{0.04275}$	(16)
C-141	$(\pi_1) = 2.2416\ (\pi_2)^{-1.0268}\ (\pi_3)^{0.0568}\ (\pi_4)^{-0.08735}$	(17)
F-4	$(\pi_1) = 4.839\ (\pi_2)^{-1.0694}\ (\pi_3)^{[0.74382 + 0.03347\ \%\ SP]}$ $\cdot (\pi_4)^{-0.12555}$	(18)

Table 61.—727 Wet Runway Model-to-Simulator Correlation

$$(\pi_1) = 1.7801\,(\pi_2)^{-1.12[illegible]}\,(\pi_3)^{[.1338\quad]}\,(\pi_4)^{-.09548}$$
$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.167	1.7801	7.4893	.9238	.3441	4.238	4.242	-.1	BASELINE
"	"	"	"	.3311	4.078	4.231	-3.6	MAX. WT.
"	"	"	"	.3668	4.517	4.102	-	MIN. WT.
"	"	"	"	.3254	4.008	3.840	+4.4	+10% V_I
"	"	"	"	.3100	3.818	3.520	-	+20% V_I
"	"	"	-	-	-	-	-	60% SP
"	"	"	-	"	-	-	-	40% SP
"	"	"	-	"	-	.	-	NO SP
"	"	"	"	.3544	4.365	4.396	-.7	120% Fe
"	"	"	"	.3298	4.062	4.020	+1.0	80% Fe

Table 62.--737 Wet Runway Model-to-Simulator Correlation

$$(\pi_1) = .4642\ (\pi_2)^{-.7647}\ (\pi_3)^{[.2346\ -.1265\%SP]}\ (\pi_4)^{+.04881}$$
$$= K\ (\pi_2)'\ (\pi_3)'\ (\pi_4)'$$

$\overline{\overline{\pi}}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.141	.4642	4.4729	.9863	1.6855	3.452	3.450	0	BASELINE
"	"	"	"	1.7536	3.591	3.762	-4.5	MAX. WT.
"	"	"	"	1.6623	3.404	3.276	+3.9	MIN. WT.
"	"	"	"	1.7323	3.547	3.463	+2.4	+10% V_I
"	"	"	"	1.7764	3.638	3.496	+4.1	+20% V_I
"	"	"	1.1962	1.6855	4.186	3.985	+5.0	60% SP
"	"	"	1.3264	"	4.642	4.831	-3.9	40% SP
"	"	"	1.6188	"	5.665	5.557	+1.9	NO SP
"	"	"	0.9863	1.6[illegible]4	3.421	3.513	-2.6	120% F_e
"	"	"	"	1.7040	3.489	3.365	+3.7	80% F_e

Table 63.—747 Wet Runway Model-to-Simulator Correlation

$$(\pi_1) = .3748\,(\pi_2)^{-.815}\,(\pi_3)^{[.3576\,-\,.0695\%SP]}\,(\pi_4)^{.4275}$$

$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\overline{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.125	.3748	5.4453	1.4603	1.5329	4.569	4.571	0	BASELINE
"	"	"	"	1.5532	4.629	4.706	-1.6	MAX. WT.
"	"	"	"	1.4853	4.427	4.321	+2.4	MIN. WT.
"	"	"	"	1.5523	4.626	4.672	-1.0	+10% V_I
"	"	"	"	1.5710	4.682	4.679	0	+20% V_I
"	"	"	1.7000	1.5329	5.318	5.294	+.4	60% SP
"	"	"	1.8393	"	5.754	5.779	-.4	40% SP
"	"	"	2.1706	"	6.791	6.783	+.1	NO SP
"	"	"	1.4603	1.5211	4.533	4.865	-6.8	120% Fe
"	"	"	"	1.5478	4.613	4.393	+5.0	80% Fe

Table 64.—C 141 Wet Runway Model-to-Simulator Correlation

$$(\pi_1) = 2.2416\,(\pi_2)^{-1.0268}\,(\pi_3)^{[\,.0568\,]}\,(\pi_4)^{-.08735}$$

$$= K\,(\pi_2)'\,(\pi_3)'\,(\pi_4)'$$

$\bar{\pi}_2$	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	% ERROR	CONDITION
.225	2.2416	4.6257	1.0092	.3871	4.051	4.052	0	BASELINE
"	"	"	"	.3705	3.877	4.026	-3.7	MAX. WT.
"	"	"	"	.4261	4.459	4.365	+2.1	MIN. WT.
"	"	"	"	.3682	3.853	3.814	+1.0	+10% V_I
"	"	"	"	.3518	3.681	3.556	+3.5	+20% V_I
"	"	"	-	-	-	-	-	60% SP
"	"	"	-	"	-	-	-	40% SP
"	"	"	-	"	-	-	-	NO SP
"	"	"	1.0092	.3965	4.149	4.186	-.9	120% F_e
"	"	"	"	.3750	3.924	3.940	-.4	80% F_e

Table 65.—F-4 Wet Runway Model-to-Simulator Correlation

$$(\pi_1) = 4.839\ (\pi_2)^{-1.069[illegible]}\ (\pi_3)^{[.7498\ +\ .03347\%SP]}\ (\pi_4)^{-.12555}$$

$$= K\ (\pi_2)'\ (\pi_3)'\ (\pi_4)'$$

π_2	K	$(\pi_2)'$	$(\pi_3)'$	$(\pi_4)'$	PREDICTED (π_1)	ACTUAL (π_1)	%ERROR	CONDITION
.278	4.839	3.9313	.8772	.1735	2.895	2.894	0	BASELINE
"	"	"	"	.1570	2.620	2.792	-6.1	MAX. WT.
"	"	"	"	.1837	3.065	3.092	-.9	MIN. WT.
"	"	"	"	.1613	2.692	2.575	+4.5	+10% V_I
"	"	"	"	.1509	2.518	2.304	-	+20% V_I
"	"	"	1.1389	.1735	3.759	3.768	-.2	60% SP
"	"	"	1.2970	.1735	4.281	4.270	+.3	40% SP
"	"	"	1.9604	"	6.471	6.478	-.1	NO SP
"	"	"	.8772	.1852	3.091	3.114	-.7	120% [illegible]
"	"	"	"	.1490	2.487	2.678	-7.1	80% Fe